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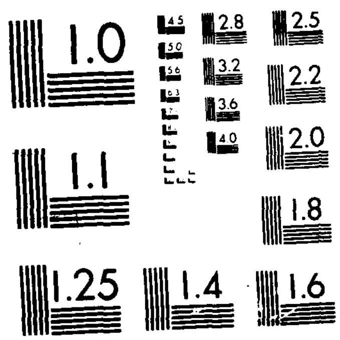
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# THESIS

TARGET SELECTION SCHEMES

by

Bernard C. Hughes, Jr.

March 1988

Thesis Advisor: Donald R. Barr

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# Target Selection Schemes

by

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Captain, United States Army
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Submitted in partial fulfillment of the
requirements for the degree of

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## ABSTRACT

This thesis investigates and subjectively evaluates four high resolution combat models' algorithmic depiction of a direct firer's target selection under combat conditions. The target selection algorithms of the Janus(T), Janus(L), Carmonette, and STAR models are investigated in detail. The models' target selection algorithms are analyzed first with respect to a direct firer's target selection as dictated by doctrine and then compared with each other. The evaluation showed there is a parallelism between the model builders decision logic and doctrinal rules. The benefits derived from target selection algorithms far outweigh their inability to accurately depict the intangible variables of actual combat. Use of the models allow the Army's leaders to sharpen their tactical skills and provide a means to analyze results of combat decisions in a non-combat environment.

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# I. INTRODUCTION

Imagine yourself serving in the United States Army as a young infantryman. You have received extensive training on combat doctrine and tactics since enlisting seven years ago. To date the closest you have come to actual combat is when your unit participated in " REFORGER " two years ago. Suddenly one morning at 0200 hrs, you are awakened by a phone call notifying you that your unit has been put on alert. Spontaneously, you grab your duffle bags and head to the unit since alerts are routine occurrences in an infantry unit. In the back of your mind, however, you can't help wondering about the fact that this alert was called two hours earlier than usual and when the First Sergeant called there was something different about his voice. As it turns out, your suspicions were not unwarranted; three days later your unit has been deployed, and you find yourself in a foxhole! Everything has happened so fast that you are having trouble coming to grips with the fact that this is the real thing. However, the live round that just landed a few feet from your fighting position convinces you! Now, you have just one question, "How do I survive?". Thinking back to your past doctrinal training you recall: select the target that poses the greatest threat; ensure the selected target is within your search sector (SS); and only select those targets which you have the capability of killing. You realize that your training has also exposed you to tactics and methodologies of combat; but under the circumstances these doctrinal strategies are the only ones that come to mind. Despite the fact that you are not exactly sure which target or targets to fire at, you react to your training by automatically taking up a good foxhole position and prepare to do your best.

A direct firer under actual combat conditions can rely, to a certain extent, on his past training in combat doctrine (WHAT to do) and tactics (HOW to do it). However, the firer is also influenced by intangible variables causing a degree of uncertainty during combat. The level or quality of training received, morale of the unit, and leadership capabilities within the command are examples of intangible variables. What methods does the Army currently employ to depict the doctrinal, tactical and intangible aspects of a direct firer's target selection in their combat models? This is a very important question because these aspects or factors could significantly impact on the target selected, duration and outcome of the battle, and simultaneously effect the life of the soldier.

The Army currently uses several computer simulation models as a means of depicting and analyzing combat doctrine and tactics. The objective of this study is to investigate the desired effects or goals of direct fire target selection algorithms within four high resolution combat simulation models: Janus TRASANA (T), Janus Livermore (L), Carmonette, and STAR. What degree of fidelity should these algorithms be expected to achieve in depicting a direct firer's target selection under actual combat conditions? A clear solution to this problem has not appeared. Additionally, there has been very little done in any study of the target selection process. The intent of this thesis is to offer a subjective evaluation with regard to the degree of fidelity algorithms should be expected to have in depicting a direct firer's target selection under actual combat conditions. The purpose of this study is not to determine an approved solution to the aforementioned problem, but rather to subjectively evaluate it. Hopefully, this approach will result in meaningful recommendations which contribute to the further development of target selection methodologies within combat models.

The methodology of this thesis is to evaluate the target selection algorithms of several well known combat models currently employed by the Army's modeling community. This procedure necessitates research of the target selection algorithms and decision rules developed by the model builders. As a result, an in-depth description of each model's target selection algorithms is given, coupled with a comparison of these algorithms.

To facilitate understanding of the target selection process, Chapter II begins with a description of target selection procedures that should be followed in actual combat. The remainder of the chapter addresses the intricacies of target selection that should be considered by model builders in their development of target selection algorithms. Chapter III presents an overall description of the four high resolution combat models with an in-depth discussion of their target selection methodologies. Chapter IV gives an analysis of the different target selection methodologies. Chapter V submits conclusions and recommendations for further study. Additionally, a listing of all the acronyms used within the text of this study is provided as an appendix.

# II. BACKGROUND

## A. TARGET SELECTION UNDER ACTUAL COMBAT CONDITIONS

The purpose of this chapter is twofold. First, it provides the reader with information pertaining to how targets should be selected in actual combat. Secondly, it presents the major features of target selection that should be considered by builders of target selection algorithms. The goal of these algorithms is to give an accurate depiction of target selection under combat conditions. The words "accurate depiction" are subjective and emphasize the fact that this study is not intended to derive an optimal target selection methodology.

Before one can gain an appreciation of the bases of the target selection methodologies currently used within combat simulation models, it is important to understand what these methodologies are trying to depict. Therefore, the target selection procedures that are supposed to be adhered to in actual combat must first be addressed. Target development is an integral part of the target selection process in actual combat. It begins with intelligence preparation of the battlefield (IPB).

The IPB process is a systemic approach to analyzing enemy doctrine combined with weather and terrain, the mission, and the specific battlefield environment. In addition to its information processing function, the IPB also provides a basis for accomplishing situation and target development by assessing enemy capabilities and vulnerabilities. The IPB process is accomplished by the G2, as the intelligence coordinator, assisted by Order of Battle (OB) technicians, and intelligence analysts of the All Source Production Section (ASPS), the terrain team, and the Air Force weather team. [Ref. 1: pp. 33-35]

Five steps comprise the IPB process. The first step is threat evaluation which consists of a detailed study of enemy forces, their composition and organization, tactical doctrine, weapons and equipment, and supporting battlefield functional systems. The objective of this step is to determine enemy capabilities and how they operate relative to their doctrine and training. The second step is the evaluation of the specified battlefield areas of operation and interest. The third step is a terrain analysis which incorporates the five factors of OCOKA [Ref. 1: p. 38]:

- Observation and fields of fire,
- Concealment and cover,
- Obstacles,
- Key terrain, and
- Avenues of approach and mobility corridors.

The fourth step is weather analysis which provides information on the impact of weather on both friendly and enemy capabilities. Step five, the last step of the IPB process, integrates enemy doctrine with weather and terrain data.

Threat iteration, a sequential process, is accomplished through the development of situation, event, doctrinal, and decision support templates. These templates also provide in-depth information with regard to possible enemy courses of action and provide the basis for high value target (HVT) analysis [Ref. 1: p. 39]. These templates provide a predictive tool since they tell the analyst in advance what the enemy can do and is currently doing. The culmination of this sequential process is the development of the decision support template. The decision support template relates events, activities, and targets of the event template to the commander's decision requirements. The decision support template provides the planning basis required for the commander to influence enemy actions and the target development process. [Ref. 1: p. 40]

Target development is performed by the ASPS which is an important part of the *all-source* intelligence analysis and production process. The target development and situation development processes, which are closely related, emerge simultaneously as a result of the IPB and analysis functions discussed previously. Target development provides targeting information to support the commander's tactical plans. The objective of this process is to provide direct or correlated targeting data which meet the commander's target selection standards. The commander uses these data for immediate fire and maneuver in the close-in battle [Ref. 1: p. 44]. Direct targeting data are the identification and location of targets. This information is reported directly to fire support elements (FSEs) for attack and normally occurs when accurate detection, identification, and location of a target are immediately available for fire support use. Armor targets acquired by ground surveillance radars is an example of direct targeting data. The process of correlating data is somewhat different in that results are obtained by comparing or correlating information from multiple sources to accurately fix a target. The incorporation of target value analysis within this process is indicative of its complexity.

Target value analysis is a methodology for identifying high value targets. It uses IPB templating which is accomplished prior to the battle, thereby enabling the commander to quickly select and attack specific targets. When faced with a numerically superior enemy force, target selection is especially critical because commanders may not have enough resources to attack every target acquired. As a result, target value analysis is geared toward determining which targets should be attacked to achieve the greatest tactical benefit for the resources expended. Target value analysis determines [Ref. 1: p. 44]:

- the critical targets,
- when these targets should be attacked, and
- where these targets should be attacked.

Target value analysis links the effects of attacking a target directly to target behavior. Target value analysis begins in IPB by a detailed analysis of enemy doctrine, tactics, equipment, organizations, and expected behavior. The information deduced from this analysis is used to assess how, in each tactical formation, the enemy is most likely to respond when confronted with different tactical situations. The target value analysis provides a comprehensive means of determining which targets should be attacked to maximize tactical benefit in a given situation [Ref. 1: p. 45].

The process of target selection in actual combat is by no means simple. While target value analysis is a very useful methodology, the soldier has the ultimate responsibility of target selection during actual combat. The information received by the commanders as a result of target value analysis can only serve as guidance. In the heat of battle, many unforeseen circumstances may arise, and all the prior preparation and intelligence reports could be quickly nullified. Still, the commander must influence the thought process of the soldiers in his unit. The soldiers who find themselves in a situation of having to select a target at which to fire should determine those targets which should be attacked for the greatest tactical benefit. Determining which targets meet this criteria is the crux of the target selection problem. However, this is easier said than done and extremely difficult to incorporate into combat simulation models.

## B. TARGET SELECTION ALGORITHMS OF COMBAT MODELS

Computer simulation models are a primary means of analyzing behavior of military forces engaged in combat [Ref. 2: p. 1-1]. An interesting phenomenon intrinsic to this analysis is the variety of methods used by different models to depict a direct firer's target selection. The development of target selection algorithms vary in degree

of complexity among the different combat models. Nevertheless, there are still basic guidelines or doctrine that should be considered by model builders during this process.

Target detection and acquisition are two processes instrumental to a model's target selection function. Target detection means merely being aware of an enemy unit's presence, whereas target acquisition is defined as the process of locating and identifying an enemy unit. The distinction between the two is one of refinement. The preceding definitions manifest the fact that a target must be detected prior to being acquired [Ref. 5: p. 21]. All of the combat models discussed in this study use the Night Vision Electo-Optics Laboratory (NVEOL) detection model to represent detection and acquisition of targets [Ref. 7: p. 352]. For the purpose of this study, the following assumption is made: a target must be acquired before it can become eligible for selection and subsequent engagement.

Four procedures or steps are used by model builders to algorithmically depict a target selection function. The first process is target definition followed sequentially by target value assessment (TVA), target priority schemes, and target selection and engagement [Ref. 2: p. 11-2].

## C. TARGET DEFINITION

Target definition (as it pertains to direct firers) is a means by which enemy targets (personnel, equipment, or real property) are grouped for engagement and classified by target type. The three basic target types are point, area, and linear. The following provides an example of the three basic target types engageable by a direct firer [Ref. 2: p. 11-3]:

- point - enemy tank,
- area - enemy infantry, and
- linear - column of tanks.

A point target is usually one in which a single target occupies a single location. An assumption inherent in a direct firer's point target is that the dimensions of the target are small in comparison with range between the weapon and target.

A target which is described as two - dimensional is classified as an area target. Simply stated, an area target is a group of target elements distributed over a given area. The number of elements in a specified area is a key discriminator between point and area targets. The distinction may be firer weapon system dependent since a target might be classified as a point target to one system and an area target to another.

Another facet of target definition is stationary versus moving targets. A stationary ground target is one that is fixed while under engagement, whereas any ground target that possesses nonzero velocity is classified as a moving target [Ref. 2: p. 11-4 ].

A linear target, as the name suggests, is a line or column of elements. A column of tanks or trucks which will often be on the move (i.e, moving targets) is an example of a linear target. This example which has all the same type elements (all tanks or all trucks) provides an excellent lead into the final type of target (simple) that will be addressed. Simple targets are those whose elements are functionally independent. As a result, the kill effects on simple targets are cardinal (i.e., each element in the target must be killed in order to kill the entire target). The elements of a simple target may be similar, as in the linear target example, or dissimilar. Additionally, these targets can be fixed or mobile. The categorization can be even further reduced based on the elements spatial relationship with one another. Simple area targets in which all elements are of the same type are classified as homogeneous. For example, trucks parked in a motorpool or a deployed infantry company both constitute a homogeneous, simple area target. On the other hand, simple targets can be classified as nonhomogeneous (i.e., having elements of different types). A composite infantry - tank force whose target elements would be the individual infantrymen and the individual tanks depict a nonhomogeneous, simple area target. [Ref. 2: p. 11-3]

The complexities which should be considered in the development of target selection algorithms are evident. Accurate target definition alleviates some of the difficulties which could be encountered by a modeler in depicting subsequent steps of the target selection function (i.e., TVA, target priority, or target selection and engagement). These difficulties will be addressed in ensuing paragraphs as more of the features pertaining to target selection are discussed. The target selection function is analogous to the step function. It is a progressive procedure with each succeeding step depending on the previous one. Target definition is the first step of the target selection function. Once the target has been defined, it must next be assessed with regard to its worth.

## D. TARGET VALUE ASSESSMENT

After targets have been defined they are then placed into target classes based on similarities. The next step in the target selection process is to assess the targets in terms of the relative value or worth a firer places on it. TVA and target worth are used interchangeably throughout the combat modeling community. According to

DARCOM-P 706-101, [Ref. 2], there are two approaches to establishing target worth. In the first approach, the worth of a target may be construed as the economic value of resources consumed to create the target. The second approach relates the worth of the target to its utility in combat. The concept of "utility" can be interpreted as a number which lies between zero and unity, zero representing a useless target, and unity standing for maximum usefulness attainable in a given situation [Ref. 2: p. 11-5]. The second approach appears to be more useful in developing algorithms that assess target values. A combatant has very little, if any, concern about how much it costs the opposing forces to create targets. His primary interest is the tactical value of a target.

Target worth, as it applies in the second approach, is a measure of the target's usefulness to the enemy as a threat to friendly forces (i.e., the potential damage or inconvenience it represents to the opposing force). An enemy weapon system in a covered position with good fields of fire is a valuable target since it can destroy or delay a large number of friendly combat elements. As previously stated, target worth is a measure of a target's usefulness to the enemy, but quantifying it is another issue altogether. A basis for computing target values could be provided in the form of a model. A model with the capability to compute measures of effectiveness of opposing forces in terms of numbers and types of force element, then systematically vary force compositions between runs, could provide a basis for determining target values.

The change in value of a target during the course of the battle is a very important aspect of the TVA process that should impact significantly on target selection. The failure of a combat modeler to properly integrate this facet of TVA into the target selection function could result in continuing to engage a target that has already been killed, for example. To further illustrate this point, the locations of enemy weapon systems change during the course of the battle. A tank platoon that penetrates the opposing main line of resistance incurs a quantum increase in its value because the damage potential of these elements has increased substantially. [Ref. 2: p. 11-5]

It is evident that TVA highlights several more of the intricacies that should be involved in the development of target selection algorithms. TVA is a complex and judgmental area. The process of incorporating target worth algorithms into combat models could prove to be extremely difficult; nevertheless, it's something the model builders should investigate. Just as target definition laid the ground work for TVA, TVA provides the basis for the establishment of target priority schemes.

## E. TARGET PRIORITY

Target priority schemes are based on several factors: range, estimated threat, exposure, detection status, time since last fired or moved, number of other weapons firing at the target, fire sector, and turret orientation of the target, according to Technical Report 571, "Human Factors Representation for Combat Models" [Ref. 3: p. A7]. The model builder is faced with the challenge of incorporating these factors into algorithms that represent the target selection function of combat models.

DARCOM-P 706-101 offers two approaches to target priorities, just as it did for TVA. First, target priorities can be imbedded in decision mechanisms that assign targets to weapon systems for engagement. Second, target priorities can regulate the volume of fire to be delivered on each target type or class. In actuality, however, both approaches give equivalent results since repeated application of decision mechanisms will determine relative volumes of fire by target class.

The TVA process, which establishes a basis for determining the relative values of targets, provides a means for target assignments of direct fire weapon systems. The rank ordering of these targets (based on their relative values) results in a list for each of the direct fire weapon systems. These lists are known within the modeling community as target priority lists. Target priority lists involve a sequential methodology where the maximum target worth is prioritized 1, the second highest target worth is 2, and so on, until all engageable targets are exhausted. Comparatively, commanders under actual combat conditions, rely on their intuition or subjective judgment and intelligence information gathered during IPB to determine which weapons will be assigned to different targets. [Ref. 2: p. 11-6]

The development of algorithms which implement the factors of target priority schemes and generate output that can be analyzed with regard to appropriate mixes of weapon capabilities is another modeling problem related to target selection methodologies. In some models, targets are selected from alternative priority lists based on either target value or danger of the target (perceived threat). Lists to be used by any firer are pre-specified by the user's input "orders". These priorities, usually expressed in terms of ordinal numbers, are an important input to the combat models. For example, an infantry battalion may be assigned the following priorities for the corresponding subjectively selected targets [Ref. 2: p. 11-6 ]:

1. BMP -1st priority,
2. tanks -2nd priority, and
3. infantrymen -3rd priority.

This illustration is very simple and readily amenable to algorithmic implementation. However, situations could arise which introduce complexities into this seemingly simple concept. The following depicts just such a situation: a weapon crew has line of sight (LOS) on a BMP when suddenly LOS is obtained on another BMP which is also in the crew's area of search (AOS). What happens in the target prioritization process when ties occur? Clearly, target selection within a combat model can be a complex process. The ways in which the algorithms of individual combat models represent such situations will be discussed in the next chapter.

In summary: there are many intricacies involved in target prioritization as evidenced by the factors which go into determining the target priority lists. Model builders should take many things into account. It is no wonder that to date there is no single "approved solution" to establishing target priority lists. If one were to look at the target priority algorithms of several different combat models, he would not find any two that were identical. Similarities (dictated by doctrine) would exist, but for the most part the establishment of target priorities is subjective in nature. The degree to which doctrine versus subjectivity or expert opinion is incorporated into the algorithms is dictated by the model builder.

## F. TARGET SELECTION AND ENGAGEMENT

Target selection and engagement is the process of assigning a weapon system to a target. This weapon assignment is based on the intentions of inflicting some expected damage and relies heavily, but not solely, on the target priority lists previously discussed. The following equation illustrates an approach that model builders might want to investigate and implement into their target selection and engagement algorithms [Ref. 2: p. 11-8]:

$$E(i,j) = Pk(i,j) \times V(j), \qquad \text{(eqn 2.1)}$$

where E(i,j) = expected damage for the ith weapon against the jth target,

Pk(i,j) = kill probability for ith weapon against jth target, and

V(j) = value of jth target.

The dimension of E(ij) and V(j) is the unit of value assigned in the analysis. The parameter Pk(ij) depends upon the probabilities of

1. locating the target,
2. the weapon system having ammunition and being operable,
3. the probability of hitting the target, and
4. the probability of destroying the target if it is hit.

The target selection and engagement process is similar to those of target definition, TVA, and target priority in that it too reveals more complex elements which appear to be critical to the target selection function.

As previously noted, target priority is not the only basis for the target engagement process. Some additional guidelines which complement target prioritization are as follows [Ref. 2: p. 11-8].

1. Engagements assigned to weapon systems (i.e., certain weapon systems engage certain types of targets).
2. Regulate the volume of fire to be delivered on each type of target.
3. Don't engage a target that is invulnerable (i.e., a particular type of weapon that has a Pk = 0 against a specific type of target should not engage this target).
4. Engage targets at the greatest range possible.
5. Each assignment of a weapon system to engage a target can be associated with some expected damage.
6. Maximize the total expected damage (i.e., those targets whose destruction will inflict the most damage on opposing forces).

These guidelines, commonly referred to within the Army's modelling community as "engagement rules", highlight some of the key facets of the target selection and engagement process. Each of the above listed guidelines is in some way related to either one or all of the four steps which comprise the target selection function. The four processes (target definition, TVA, target priority, and target selection and engagement) should be taken into account by the model builder.

## G. PAST STUDIES

It was initially thought that studies conducted on target selection methodologies would be readily available. However, this was not the case. Research revealed that

general studies conducted on a direct firer's target selection algorithms are scarce. A few studies were found in reference, but attempts to obtain them failed. For example, a memorandum for record on the Commander's Individual Thermal Vision Engagement Rules for JANUS mentioned two studies; the Armor Investment Strategy Study and the Battlefield Management System Evaluation. However, the applicability of these studies to this thesis could not be evaluated since the classification of the first study prevented its being sent through the mail, and the second study had not yet been published. Attempts to obtain other studies resulted in similar outcomes. According to Mr. Larry Vowels of the Directorate of Combat Development (DCD) at the U.S. Army Armor School, the currently existing studies on combat models deal very little with the modeling aspects, but primarily provide justification of the system (e.g., cost effectiveness analysis) [Ref. 4]. One useful study was a thesis by Captain Glen Broussard [Ref. 5]. Broussard's thesis, entitled "A Dynamic Study of Factors Impacting on the Tank Commander's Target Selection Process", developed a target selection model based on regression with target selection data gathered by questioning sixty four tank commanders [Ref. 5: p. 2 ]. It is rather surprising that the target selection problem has not received more attention.

# III. TARGET SELECTION ALGORITHMS OF INDIVIDUAL COMBAT MODELS

## A. JANUS TRASANA (T)

### 1. Model Description

The JANUS TRASANA (T) combat simulation model is the first of four models to be discussed with respect to target selection algorithms. However, prior to addressing these algorithms a general description of the overall model is presented.

The Lawrence Livermore National Laboratory prototype model, Janus(L), was used as a starting point for the Janus(T) combat simulation model. The further development of Janus(T) began in 1983, and it is currently maintained by the US Army TRADOC Analysis Command-White Sands Missile Range (TRAC-WSMR), formerly the US Army TRADOC Systems Analysis Activity (TRASANA), located at White Sands Missile Range, New Mexico.

TRASANA was assigned the JANUS Acquisition and Development project by TRADOC in December of 1980. In conjunction with the development of Janus(T), TRASANA was tasked to provide technical support within TRADOC and other Army organizations for continued development, use, and export of the model.

Currently, Janus(T), uses Army developed algorithms and data to model combat processes. The TRASANA data base utility "Forms" is used for establishing data bases and interactive data maintenance. The group of programs comprising Janus(T) consists of approximately 85,000 lines of code written in VAX - 11 FORTRAN which is a structured Digital Equipment Corporation (DEC) extension of standard FORTRAN - 77.

The Janus(T) model is an interactive, two-sided, closed, stochastic, ground combat simulation. The players plan and conduct tactical operations and make tactical decisions based on the battle situation appearing on a map-like display and on-call status reports. The model includes most ground and air systems involved in offensive and defensive ground combat operations and is designed with the capabilities of handling force-on-force conflicts of up to a U.S. battalion versus an opposing force's regiment.

The model uses high-resolution terrain maps. Janus(T) models individual systems moving, searching, detecting, and firing over a specified three dimensional

terrain representation. The simulation represents each unit as an individual symbol on a graphic display of the terrain base whose separate parts include elevations, roads, rivers, cities, foliage, engineer barriers, and natural barriers. The terrain resolution is variable with possible 25, 50, 100, and 200 meter terrain grids. The digital terrain map displayed is 200 by 200 cells which allows for the following display sizes of 5, 10, 20, and 40 kilometers. [Ref. 7: pp. 5-7]

The preceding description provides the reader with general information pertaining to the Janus(T) model. Next, those general characteristics that apply to the four processes of target selection discussed in the previous chapter are discussed in more detail.

### 2. Target Definition

The structure of the Janus(T) model is such that the user or gamer has the responsibility of defining targets. The gamer accomplishes initial target definition through the use of codes which are input to the system functionality table. These targets can be further characterized when the gamer accesses a data base. Although the topic of this section is target definition, it is important to note that system type characteristics for both sides are established by using this table. For the present discussion system types for the opposing forces are targets and those for the friendly forces are direct fire weapons. The same procedures are employed to develop system types, regardless of whether a force is friendly or opposing. Table 1 is a sample form used by the gamer to define targets [Ref. 7: p. 97].

## TABLE 1

## SYSTEM FUNCTIONALITY

| | | |
|---|---|---|
| 1st Sensor Type....... | ## | 1-->15 : 15 = Automatic Target Recognition |
| 2nd Sensor Type....... | ## | 1-->15 : 15 = Automatic Target Recognition |
| Designator....... | ## | 1 = G1 G2 |
| Minefield Dispenser....... | ## | 1 = Moppms, 2 = Heli, 3 = Ground Veh |
| Engineer....... | ## | 1 = Tank, 2 = AVLB, 3 = CEV |
| Fire Category....... | ## | 1 = DF, 2 = ARTY, 3 = Both |
| Flyers....... | ## | 1-->16 : 3 = FOGM, >10 = ATR sensor |
| Logistics....... | ## | 1 = ASP FARRP |
| Movers....... | ## | 1 = Wheeled, 2 = Tracked, 3 = Footed, 4 = Towed |
| Radars....... | ## | 1-->9 Air Def Radars |
| Smoke Capability....... | ## | 1 = Exhaust, 2 = Projectiles, 3 = Both |
| Surveillance....... | ## | 1 = Chem Detector |
| Swimmers....... | ## | 0 = no , 1 = Swims |

Only those codes of the system functionality table applicable to defining direct fire targets are discussed here. The symbols # and *, on this and succeeding tables, represent codes which are input by the user. The following is a brief description of these codes:

a. Sensor Type

Each system is allotted two sensor types. The simulation will switch to the alternate sensor if 20 seconds elapse and there are no detections made. An additional requirement is that the unit is not engaging any opposing force.

b. Engineer

This functionality flag code should be set to the appropriate capability of a particular system. A flag set at zero means the unit has no engineer capability.

c. Fire Category

If a system is to engage units directly, and does not fire artillery, its "Fire Category" should be set to "1". This "Fire Category" fits the scope of this thesis perfectly.

d. Movers

This is the key flag for defining direct fire targets since the "Movers" (wheeled, track, footed, and towed) comprise the majority of direct fire targets.

The system functionality codes appear to provide an efficient means of initial target definition. These codes, input by the gamer, establish the basic targets. Additionally, the gamer has the responsibility for more intricate target characterization.

The gamer is provided the opportunity to depict targets in greater detail by accessing data from the model's Combat Systems Data Base. "The combat systems data editor (CSDATA) is used to prepare and maintain the data for units that are simulated by Janus(T)" [Ref. 7: p. 65]. The CSDATA provides a menu of several options available to the gamer for enhancing target definition. The gamer uses his own discretion in choosing these options. A simulation of a direct firer engaging compatible targets would probably result in the following options being selected: System Weapons Ordnance, System Ordnance by Target, and System General Characteristics. [Ref. 7: p. 67]

The System Weapons Ordnance option is used to define the targets with respect to ammunition availability. Each system can have up to 10 direct fire weapons that it may use against opposing force systems. These 10 direct fire weapons for each system are selected from a list of 250 possible weapons. Specifying these 10 weapons further develops the target definition process. The form presented in Table 2 (below) shows how the basic load for each weapon can be specified. Additionally, a second weapon can be specified for use when the first weapon has exhausted all of its ammunition. [Ref. 7: pp. 102-104]

TABLE 2
SYSTEM WEAPONS/ORDNANCE

| System Weapon Ord | Absolute Weapon Ord Number (1-->250) | Weapon/Ord Name | Basic Load | System Weapon Ord to use If Ammo Expended (1-->10) |
|---|---|---|---|---|
| 1 | ### | **************** | ###### | ## |
| 2 | ### | **************** | ###### | ## |
| 3 | ### | **************** | ###### | ## |
| 4 | ### | **************** | ###### | ## |
| 5 | ### | **************** | ###### | ## |
| 6 | ### | **************** | ###### | ## |
| 7 | ### | **************** | ###### | ## |
| 8 | ### | **************** | ###### | ## |
| 9 | ### | **************** | ###### | ## |
| 10 | ### | **************** | ###### | ## |

The Janus(T) model accesses both the ammunition availability and basic load of each weapon or target. Having access to a weapon's basic load provides a means of quantifying (weapon and target) ammunition by availability and type. Knowledge of a target's basic load is critical to assessing its worth (i.e., the next step of the target selection function).

The System Ordnance by Target and Range option requires the user to specify which direct fire weapon (1-10) a system must use against each possible opposing force target. The form used to input these data has the capacity to handle fifty opposing force systems or targets at a time. A revised sample of this form (ten opposing forces - three data fields) is shown in Table 3 below [Ref. 7: p. 106].

TABLE 3

WEAPON/ORDNANCE CHOICE BY TARGET AND RANGE

| TGT | W1 | RANGE | W2 |
|---|---|---|---|
| ### | ## | ##.## | ## |
| ### | ## | ##.## | ## |
| ### | ## | ##.## | ## |
| ### | ## | ##.## | ## |
| ### | ## | ##.## | ## |
| ### | ## | ##.## | ## |
| ### | ## | ##.## | ## |
| ### | ## | ##.## | ## |
| ### | ## | ##.## | ## |
| ### | ## | ##.## | ## |

Going from left to right on the table, the data fields are designated as follows: first W1 is for the relative weapon number to use against that target (TGT); second, RANGE is for the range from the weapon system to the target; and third W2 is for an alternate weapon that also satisfies the range requirements, but is not the primary weapon system chosen for that target. As previously stated, the same options are used to select targets and weapons systems for both forces. The System Ordnance by Target option has significant impact on target definition since the weapons (W1 and W2) selected by the gamer from the data base will become the targets of the opposing force and vice versa.

The System General Characteristics option addresses some of the characteristics of target definition mentioned in the preceding chapter. The following is a list of these characteristics [Ref. 7: pp. 70-71].

1. "CREW SIZE" is not used by any of the Janus(T) programs.
2. "THERMAL CONTRAST" is the difference in degrees centigrade between a system and the background. The twelve classes of contrast in degrees centigrade are 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 6.0, and 7.0. Two contrast classes are specified for each system, fully exposed and hull defilade.
3. "MINIMUM DIMENSION" is used by the detection routines. Imagine the smallest shoe box that would just contain the system. Pick the smallest dimension of that box for this input.
4. "ROAD SPEED" is used to determine unit speed. Units move at this speed when on a road. Off road speeds are determined by reducing the road speed based on slope and vegetation or built up areas in the unit's location. Gamers find that units are much easier to control when they are all traveling at approximately the same speed. It is recommended that an average road speed for all units be determined and this road speed input for each system.
5. "RANGE OF PRIMARY WEAPON" limits the maximum range at which units of this system type will engage an opposing force unit
6. "MAGNETIC SHADOW" is the maximum distance to either side of the system that a magnetic mine could sense and respond to the system's presence.
7. "TRACK WIDTH" is the width of one of the system's wheels or tracks.
8. "BELLY WIDTH" is the distance between the two tracks or wheels of the system.
9. "HEIGHT" determines what vertical distance above the terrain elevation is used for determination of LOS between units.
10. "VISIBILITY" determines the maximum distance away that a unit can detect another unit.
11. "INTERVAL" specifies how far elements of the same unit are from each other. Elements are in-line (one behind the other) when traveling on a road. Elements are on-line (beside each other) when traveling off the road.
12. "GRAPHIC SYMBOL" specifies which symbol created by the program "SYMBOLS" will portray a unit of this system type when Janus(T) is run.

The System General Characteristic option defines some of a target's more complex traits. These traits will provide the direct firer with additional data on which to base his target selection. There are several options which can be employed to define targets within the Janus(T) model. However, the degree of complexity involved in this definition process is strictly dependent upon the desires of the gamer. Table 4 depicts the form used by the gamer to select some of the aforementioned traits [Ref. 7: p. 72].

TABLE 4

SYSTEM GENERAL CHARACTERISTICS

System Number: ###          System Name: *****************

| | |
|---|---|
| Crew Size......................... | ### |
| Exposed Thermal Contrast Class (1 --> 12) ........ | ## |
| Defilade Thermal Contrast Class (1 --> 12) ......... | ## |
| Minimum Dimension (Meters, for Detection).......... | ##.## |
| Average Road Speed (Km Hr)........................ | ###.## |
| Range of Primary Weapon System (Km)................ | ###.## |
| Magnetic Shadow Width (Meters)...................... | ##.## |
| Track Width (Meters)............................... | ##.## |
| Belly Width (Meters)............................... | ##.## |
| Height (Meters).................................... | ### |
| Visibility (Seeing distance, Km).................... | ##.## |
| Interval Between Elements of the Same Unit (Meters)... | ### |
| Graphic Symbol...................................... | ### |

3. **Target Value Assessment**

TVA within the Janus(T) model is a one step process. It is accomplished during the initialization stage when each possible combination of direct fire unit with enemy target unit is assigned a "threshold cycle ratio" (TR) by random drawing. The NVEOL detection model is the mechanism used to assign the TR's which are instrumental to the succeeding target prioritization process.

4. **Target Priority**

Every 20 seconds of Game Time, a list of at most 5 potential target units is formed for each direct firing unit. Certain requirements must be met in order for an enemy unit to be included in this list. The firer must have LOS to the target and must resolve a sufficient cycle ratio (CR) on the target. The CR is computed by the NVEOL detection model. The target unit must be in the direct firer's search sector (SS). If there are more than 5 targets meeting these conditions, only the 5 with the most cycles are put in the list.

The computed CR must be greater than or equal to the TR, before the target is eligible to be put in the direct firer's potential target list. Recall that the TR is assigned to each possible combination of direct fire unit with enemy target unit by a random draw during the TVA process. Therefore, the target priority lists are determined by comparing computed values with ones drawn at random.

Every two seconds of Game Time, a direct fire unit attempts to acquire those units in its list of potential targets by utilizing the NVEOL model. The NVEOL model calculates a probability of detection (PD) for each potential target. Randomization is once again implemented to determine if a target is acquired. An independent U(0,1) random draw is made for each potential target and compared with the PD for that target. If the random draw is less than or equal to the computed probability of detection, the target unit is acquired and becomes eligible for selection and engagement.

5. **Target Selection and Engagement**

The target engagement and selection module, called the Direct Fire Module (DFM) within the Janus(T) community, is implemented to process a single potential direct fire event. The DFM is initially scheduled (for a particular firing unit) by the Detection Module whenever a direct fire unit detects an enemy unit. In general terms, the DFM performs the following tasks each time it is put into operation. [Ref. 7: p. 370 ]

- Determine if the firing unit can fire at this time.
- Perform target and weapon selection.
- Fire one round (or burst) and record the firing event.
- Decrement the appropriate ammo count for the firing unit.
- Calculate the round (or burst) impact time.
- Make a preliminary determination of the number of kills. At impact time determine if the kills are still valid. Record the kills, if any.
- Calculate the earliest next possible firing time for this firing unit.
- Re-schedule the DFM to run again for this same firing unit, if appropriate.

A detailed description of the DFM tasks will be presented next. The initial firing requirements, as the name implies, must be satisfied first. These requirements are as follows [Ref. 7: p. 371 ]:

- The unit must be alive and operable,
- The unit must be Direct Fire capable,
- The unit must not be currently in Hold Fire mode,
- The unit must not be currently suppressed,
- The unit must not be mounted on another unit, and
- The unit must have at least one currently detected enemy unit in its Potential Target list.

Once all of the initial firing requirements have been satisfied, the actual target selection for each (live) detected enemy unit in the firer's Potential Target list occurs. If the range to the target unit is greater than the "RANGE OF PRIMARY WEAPON SYSTEM" assigned to the firing unit's system type the enemy (target) is not engaged, but is ignored by that weapon system (See Table 4). The primary weapon (if any) assigned for use against the target unit's system type is determined. If the firing unit has rounds remaining for this weapon, select the weapon, if any. If the firing unit has rounds remaining for the alternate weapon, select the alternate weapon (See Tables 2 and 3). If no weapon can be selected, the target is ignored. If a target can be selected, the DFM simulates the firing of one round (or burst, depending on the type weapon) against the selected target. The next sequential step is to calculate a Single Shot/Burst Kill Probability (SSKP) for the selected weapon against the target unit's system type, considering:

- Range to target unit
- Motion category of firing unit (stationary or moving)
- Motion category of target (exposed or defilade)
- Aspect angle of target (head-on or flank)

If there are no targets with SSKP greater than or equal to .05 the DFM is exited. If there is only one target with SSKP greater than of equal to .05 select it. If more than one target is present with sufficient SSKP, consider the probability of selecting it as being proportional to its SSKP. This proportion, the probability of selecting each target, is obtained by dividing each target's SSKP by the sum of the SSKP's. A U(0,1) draw is then used to determine which target to select. This procedure is illustrated in Chapter 4. [Ref. 7: pp. 370-373 ]

## B. JANUS LIVERMORE (L)

### 1. Model Description

Janus(L) is a computer simulation of battlefield conflict developed by the Lawrence Livermore National Laboratory. The Janus(L) computer program models combat systems, the battlefield environment (terrain and weather), and each system's interaction with other systems and their environment (acquisition, firing, movement, etc.). The model is an event-driven, stochastic simulation written in approximately 60,000 lines of FORTRAN. The Janus(L) model currently runs on Digital Equipment

Corporation (DEC) mini-computers using the VMS operating system and Tektronix 4125 color graphics workstations. The software is operational from one or more workstations, each consisting of one Tektronix 19-inch color monitors, one or two graph tablets with pucks, and a DEC VT-100 keyboard and video terminal. The Janus(L) model can be operated in a gaming mode or a batch mode. The VT-100 terminal is used to interact with the VAX system and to set up and initialize the program. The numerical calculations required for a system level simulation in near real time are processed by a dedicated VAX 11/780 mini-computer. The data used for attrition assessment and depicting characteristics of weapons can be interactively reviewed and edited by the user during the initialization stage of the simulation. These characteristics and their impact on the target selection methodology of the Janus(L) model will be discussed in detail later.

Janus(L) allows the user to make tactical or doctrinal decisions relating to fire planning and maneuver in a competitive multi-sided environment. This is achieved by using high resolution color graphics to display the battle situation as known in near-real time and allowing people to become part of the simulation by using interactive graphics devices to plan movement and firing. This provides an opportunity to study the process of decision making and command and control. The Janus(L) model is configured to use n-views of the battlefield, where n may be 1, 2, 3, or more interactive color graphics workstations in separate rooms, each with its own view of the battle. The use of n-views and user allocation of force and terrain provides Janus(L) a flexibility to model a wide variety of battle scenarios. A small company size force defending against an enemy battalion may be modeled, or a defending division size force with brigade commanders on separate terrains or views may fight an attacking force of one or two divisions. This study will be concerned with the direct firer's target selection methodology as it pertains to the lower spectrum of scenarios mentioned (i.e., high resolution or small force levels).

Janus(L) uses digitized terrain elevations as provided by the Defense Mapping Agency. A utility program allows contour lines to be drawn to graphically represent a two-dimensional display of the three-dimensional terrain model. A graph tablet enables trees, cities, rivers, and roads to be added to the terrain. The terrain file may then be used with the scenario of forces for a simulation. The terrain may be used in the resolution available, normally 125 to 100 meter grids. The Janus(L) software system is controlled and maintained by the Conflict Simulation Center (CSC) at the

Lawrence Livermore National Laboratory [Ref. 8: pp. 1-2 - 1-3]. The preceding paragraphs describe the Janus(L) model in general terms. The discussion that follows is limited to the target selection methodology used in the Janus(L) model.

### 2. Target Definition

The Scenario Editor (SCENEDIT) is used for target definition in the Janus(L) model. SCENEDIT is an interactive program which allows the user to specify the force structure of enemy units. Further, it enables the user to review and modify information, including the detailed description of battlefield systems and conditions which make up a Janus(L) scenario. The user specifies the number of units, the type of each unit (tank, tow, etc.), and the number of elements (systems) initially in each type unit (e.g., 5 tanks in a platoon). The systems' characteristics are also defined. Some of these characteristics are: spacing between elements, size of system, height of observer above the ground, maximum visibility, maximum firing range, basic load, and road velocity.

Once the user has initially defined the targets with respect to the parameters mentioned in the preceding paragraph, he is kept aware of the target's definition status by a report, DATSPOT, generated periodically by the Janus(L) system. The DATSPOT report is started at the beginning of the simulation and updated periodically, in accordance with the specified report interval, until the simulation is terminated. The report is a statistical report indicating the individual unit status at the time of the report. A unit is comprised of one or more targets or primary weapon systems. The information items of DATSPOT which pertain to direct fire target definition are [Ref. 8: p. 2-6]:

- Clock: Simulation clock time starting at 00:00:00 of the report.
- Side: Side to which the unit and target are assigned.
- Task: Task Force to which the unit and target are assigned.
- Unit: Unit number which uniquely identifies the unit in the simulation.
- Type: System slot number of units, type number for units.
- System: System name.
- Ammo: Number of rounds of ammunition remaining for the primary weapon.
- Altamo: Number of rounds of ammunition remaining for the alternate primary weapon.
- Speed: Unit or target speed at time of report.

- Dirctn: Direction of unit or target travel/vector of target (in degrees: 0/360 = North, 90 = East, 180 = South, 270 = West).

Although target characteristics are changing throughout the simulation run, the DATSPOT report enables the user to stay abreast of these changes. Additionally, units of the Janus(L) model can be defined on the basis of changes in defilade. Defilade is an important aspect of target definition which is not addressed in the DATSPOT.

SCENEDIT is also used to define targets in terms of defilade (full, partial, or exposed). A unit in full defilade can see but cannot shoot, and can be seen only from within a minimum distance set in SCENEDIT. A unit in partial defilade can be seen from a minimum distance also set in SCENEDIT. An exposed unit, as the name suggests, is one that is not in defilade at all. The simulation or game starts out with all units in defilade (full or partial) depending on the scenario file. Target or unit movement results in a loss of defilade which subsequently leads to a loss of concealment. If a unit comes to a stop, it automatically returns to a defilade status after a minimum time set in SCENEDIT. A target's defilade status is one of the key factors involved in its definition and eventual selection for engagement. The Janus(L) model has means of defining targets based strictly on defilade.

Units which automatically change states in conjunction with target engagement are defined as "Pop-up" units or targets. "Pop-up" targets must be designated in SCENEDIT. These targets will automatically move from full defilade to partial defilade to engage targets, then return to full defilade after engagement. This option is similar to the other target definition techniques used in Janus(L) since it too is controlled by the user.

The basic load of a target is another important factor in defining a target. When the gamer creates the initial scenario file using SCENEDIT, one of the data inputs is the primary weapon system's basic load. During the initialization phase, each target is assigned a number of rounds equal to the system's basic load times the number of systems in the unit. All weapon systems begin the simulation with their authorized basic load. Every time a system fires its primary weapon system, a round is deducted from the number it is carrying. Upon depletion of its basic load, a weapon system can no longer fire and must default to an alternate primary weapon. The alternate primary weapon systems are assigned to each primary weapon system and their basic loads are assigned in the same way as described above. Each weapon

system is monitored individually in order to keep track of ammunition availability throughout the simulation, thus providing a means of assessing a direct firer's capability to engage targets [Ref. 6: p. 47].

SCENEDIT is the primary means by which targets are defined; however, one of its counterparts, the Probability of Kill Editor (PKEDIT), also provides an option. The PKEDIT Main Menu List contains the Edit Index Tables by Weapon option. This option presents a three column list of weapon systems that are in the scenario and identifies each weapon by side, system name, and weapon code [Ref. 8: p. 4-4]. The user can implement this option to verify and consolidate targets identified during the initialization stages of the simulation. While the PKEDIT program merely provides a reinforcing mechanism with regard to the target definition process, its importance to the overall target selection scheme within Janus(L) will be shown in the following discussion of target value assessment (TVA).

### 3. Target Value Assessment

The program PKEDIT creates and examines the effectiveness or value of each weapon type against each target type based on user input. The Probability of Hit (PH)/Probability of Kill (PK) file of the PKEDIT program contains information which is used by Janus(L) to resolve direct combat situations based on the scenario file. PH and PK data are defined as curves with up to six data points per curve to determine probability (expressed as a percent) of hit or kill over a given range from shooter to the target. A master PH/PK data base which is generated from available resources is maintained at the Lawrence Livermore National Laboratory Combat Simulation Center. A Master Data Base (MDB) contains all data available for each shooter/target pairing, and is referenced by PKEDIT to create scenario specific PK files. PK is the probability of kill given a hit. An example of a PH curve set when displayed for a shooter/target pair appears in the following table [Ref. 8: p. 4-5].

TABLE 5

PH CURVE SET

| Range | 0 | 1000 | 1500 | 2000 | 3000 | 0 |
|---|---|---|---|---|---|---|
| SSDF | 95 | 95 | 94 | 98 | 87 | 0 |
| SSDH | 87 | 87 | 90 | 90 | 85 | 0 |
| SSEF | 99 | 99 | 95 | 95 | 90 | 0 |
| SSEH | 88 | 85 | 88 | 82 | 80 | 0 |
| SMDF | 0 | 0 | 0 | 0 | 0 | 0 |
| SMDH | 0 | 0 | 0 | 0 | 0 | 0 |
| SMEF | 99 | 99 | 99 | 97 | 94 | 0 |
| SMEH | 88 | 89 | 90 | 85 | 80 | 0 |
| MSDF | 55 | 60 | 60 | 55 | 28 | 0 |
| MSDH | 45 | 45 | 45 | 40 | 30 | 0 |
| MSEF | 59 | 60 | 60 | 53 | 40 | 0 |
| MSEH | 40 | 43 | 43 | 41 | 35 | 0 |
| MMDF | 0 | 0 | 0 | 0 | 0 | 0 |
| MMDH | 0 | 0 | 0 | 0 | 0 | 0 |
| MMEF | 35 | 35 | 30 | 30 | 20 | 0 |
| MMEH | 30 | 30 | 25 | 20 | 15 | 0 |

Data items at the top of each column identify ranges from the shooting system. The four letters beginning each line identify the shooter's movement status (S = stationary, M = moving), the target's movement status (S = stationary, M = moving), the target's defilade (E = exposed, D = defilade), and the target's facing (H = head shot against frontal armor, F = flank shot or anything other than a head shot), respectively. The dependence of the TVA process on target definition is clearly indicated by column one of the table.

The PK curve set is similar to the PH table with the exception of the first column. A sample of this format can be seen in the following table [Ref. 8: p. 4-8].

TABLE 6

PK CURVE SET

| Range | 0 | 1000 | 1500 | 2000 | 3000 | 0 |
|---|---|---|---|---|---|---|
| MobDF | 95 | 95 | 94 | 98 | 87 | 0 |
| MobDH | 87 | 87 | 90 | 90 | 85 | 0 |
| MobEF | 99 | 99 | 95 | 95 | 90 | 0 |
| MobEH | 88 | 85 | 88 | 82 | 80 | 0 |
| FrpDF | 0 | 0 | 0 | 0 | 0 | 0 |
| FrpDH | 0 | 0 | 0 | 0 | 0 | 0 |
| FrpEF | 99 | 99 | 99 | 97 | 94 | 0 |
| FrpEH | 88 | 89 | 90 | 85 | 80 | 0 |
| MoFDF | 55 | 60 | 60 | 55 | 28 | 0 |
| MoFDH | 45 | 45 | 45 | 40 | 30 | 0 |
| MoFEF | 59 | 60 | 60 | 53 | 40 | 0 |
| MoFEH | 40 | 43 | 43 | 41 | 35 | 0 |
| KK-DF | 0 | 0 | 0 | 0 | 0 | 0 |
| KK-DH | 0 | 0 | 0 | 0 | 0 | 0 |
| KK-EF | 35 | 35 | 30 | 30 | 20 | 0 |
| KK-EH | 30 | 30 | 25 | 20 | 15 | 0 |

As was the case for the preceding table, the data items at the top of each column identify the ranges from the shooting system. The letters beginning each line identify the type of kill (Mob = mobility, Frp = Firepower, MoF = mobility or firepower, and KK = catastrophic kill), the target's defilade (E = exposed, D = defilade), and the target's facing (H = head shot against frontal armor, F = flank shot or anything other than a head shot). Each curve in this set is a function of range. If the last range value is zero, then the effective range of the weapon is the previous range value given. The PK's and range values are interpolated. The algorithm for probability of kill as it relates to direct firers is as follows [Ref. 6: p. 50].

1. Determine the weapon system used by the shooting unit.
2. Calculate the range between the shooter and the target.
3. Determine the shooter's status (i.e., is it moving or stationary?).
4. Determine the target's status (i.e., is it moving or stationary, is it in defilade or exposed?).
5. Given the status of the shooter and the target, compute PH.
6. Given the target status, compute PK.
7. Probability-of-kill equals PH times PK.

The PH and PK values provide a means of target value assessment (the higher the better) for determining target worth. The function of PH and PK values within the overall Janus(L) target selection process is not limited to the target value assessment process.

4. **Target Priority**

Target prioritization within the Janus(L) model is a two step process. First, during the initialization stage, a list of at most 5 potential targets is established for each direct fire unit just like the Janus(T) model. However, the Janus(L) model can use either of two detection models, the NVEOL or the ASARS, to generate its potential target lists. After the potential target lists have been established, targets are also acquired using the NVEOL or ASARS detection model. A target must be acquired before it is eligible for selection and engagement. The second step also occurs during the initialization stage, but does not impact on the target priority process until after a target has been acquired. A weapon selection is determined for each possible target based on the commander's target priority value (TPV). The TPVs are input in SCENEDIT during the pre-game phase of the simulation. TPVs are used to determine which weapon will be chosen to engage a specified target. The weapon assigned the TPV having the highest numerical value is selected to engage a specified target. In the event of a tie (i.e., two targets having the same priority TPV), PK becomes the discriminating factor. The weapon with the highest PK will be given the higher priority. After ties have been resolved, the target selection and engagement process is begun.

5. **Target Selection and Engagement**

The target selection and engagement process within Janus(L) is initiated by periodic checks of each unit in the simulation. These checks are to ascertain which, if any, enemy targets or units have been acquired by the direct firers. The selection and engagement procedures are the same for all firers regardless of the detection model used to generate potential target lists and acquire targets. Each entry on the direct firer's potential target list is given a weight based on the following: the commander's TPV, weapon PK against that particular target, and the reload time for the weapon selected to engage that particular target. Using these weighting factors, a random selection is made from the list. The following is the algorithm which accomplishes this [Ref. 6: p. 37]:

1. For each acquired target

   a. Weight Factor = TPV x (PK TGT/WPN RT). (eqn 3.1)

   b. For each living target in an enemy unit

      Assign Weight Factor to target.

      Add it to the target list.

2. Assign the sum of all Target Weights to Sum Weights.
3. If

Sum Weights = 0.0. (eqn 3.2)

then

there is no available target

exit.

4. *Generate a random number in the range (0.0, Sum Weights)*
5. Search the target list, tallying the system weights until the total equals or exceeds the random number. The target at this point in the list becomes the chosen or selected target.
6. If LOS from direct firer to target is blocked

   then

   GO TO STEP 7

   else assign this target to the direct firer

   exit

7. Eliminate the target from the list.

   Subtract its weight from Sum Weights.

   GO TO STEP 3.

Once target engagement has been initiated, the direct firer will continue to engage the target until [Ref. 6: pp. 32-33]:

a. The target is killed,
b. The system or firer is killed,
c. The LOS from the firer to the target is broken,
d. The firer is placed in a no shoot mode by its owning player,
e. The system's parent unit is placed in full defilade by it owning player

(exception: "pop-up" units).

Certain conditions may force a firer to try to find another target:

f. If, after a firer shoots at a target, he determines that there is another firer engageing the same target, then the firer will make a new target selection. It is possible that it may reselect the same target for the next shot. If he chooses a different target, the firer must wait its response time plus its reload time before firing.

Once a system has selected a target, there is a delay, called the "Response Time", before it engages the target. The mean value for the response time is an input parameter (each weapon system type has its own mean response time). The actual response time is generated by making a random draw from the normal distribution with the input value as the mean and standard deviation equal to 20 percent of the mean. After the first shot, each succeeding shot at the same target is fired after another delay, called the "Reload Time". The mean value for the reload time is also an input parameter (each weapon system type has its own mean reload time). The actual reload time is generated by making a random draw from the normal distribution with the input value as the mean and standard deviation equal to 10 percent of the mean [Ref. 6: p. 33].

The features of the target selection methodology employed by the Janus(L) model will be illustrated and analyzed in the following chapter.

## C. CARMONETTE/TRASANA

### 1. Model Description

Carmonette/TRASANA (C/T) is the third combat simulation model that will be discussed in this study. C/T is a Monte Carlo, critical-event sequenced, computer model capable of simulating force-on-force engagements of ground and air combat units. In order to simulate a sequence of events occurring in a battle, the simulation depends on a set of clocks which maintains the times at which the events will occur. The Carmonette model is high resolution and simulates combat battles down to the weapon system level with unit sizes ranging from the individual soldier to a reinforced battalion. There are several aspects of combat that are modeled within C/T: weapon and sensor characteristics (including rapid fire air defense weapons), helicopter and fixed wing flights, minefields and the effects of various types of terrain, smoke

obscurants, dust, and natural atmospheric conditions. Weapon (or weapon platform) activities that are simulated in the model include target acquisition, selection of target, aiming at target, firing at target, calculation of impact on the target, and resultant damage or kill of the target. Unit activities include movement, reaction to fire, artillery and mortar control, helicopter and fixed wing support, and the communication of target and command information among simulated units.

C/T is operational on the Sperry 1100/92 system at the TRADOC Analysis Command, White Sands Missile Range Facility. The recent upgrade to the Sperry 1100/92 has reduced the replication time for some scenarios to approximately 40 minutes of CPU time for about 40 minutes of battle time. The model was originally written in FORTRAN V; however, this computer language was rewritten to ASCII FORTRAN several years ago. Graphical playback of the C/T battle is possible for both debugging and analysis of terrain and battle conditions for study reports. C/T data input may be developed with an interactive automated program operational on a Hewlett - Packard 9000 called MICROCAS.

C/T uses a rectangular battlefield consisting of grid squares. The dimensions of the grid squares are user input (normally 100, 50, 25, or 12.5 meters) with the size of the squares held constant for each battlefield. Each grid square is described by elevation above sea level, vegetation and height, road trafficability, cross-country trafficability, and cover/concealment. [Ref. 9: pp. 1-2 ]

2. **Target Definition**

As was the case for the preceding models, the terminologies (targets and weapons) are used interchangeably within the C/T model. The weapons of the friendly forces are the targets of the enemy forces and vice versa.

A maximum of 127 distinct weapon types can be defined by the user. These weapons are subdivided into direct fire (of interest in this study) and indirect fire. Simulation of ballistic rounds, burst fire rounds, and guided missiles of direct fire weapons is attainable within the C/T model. The movement rates are derived as a function of vehicle type, dismounted rate, and environmental conditions. The user determines the desired unit movement rate and the model calculates the maximum achieveable rate across each grid square accounting for the environmental conditions.

Direct fire units (comprised of targets) are defined by the user, e.g., armored vehicles, soft vehicles, infantry, etc. There are two classes of units within C/T [Ref. 9: p. 2]:

a. The combat units that are assigned weapons and can engage targets, and

b. The command and control units that perform as the commanders of a force and reside as companion units of combat units.

These units are further defined by a set of highly conditional orders for each unit which are the driving force behind C.T. Each unit is given a complete set of orders which encompasses its tactics, movements, and firing doctrine. The battle is created when each side of combatants is given a set of detailed commands (orders) to obey during a specified time interval. Each order creates conditions to be satisfied to allow the unit to execute the next order. The user can give action or reaction type orders. The action type order defines conditions to be satisfied, e.g., movement of target from one grid square to another, target going from partial to full defilade, or target firing a specified number of rounds. The reaction type of order allows the unit to stop its current activity and execute a different order based on some external stream of events such as received fire, degree of losses, time, location, and survivability of friendly units.

Every unit is further identified by its characteristics: element type, whether or not it carries dismountable troops, and its commander unit. It is assigned a starting location (x,y) in the terrain box, given the capability of alternate actions and has assigned to each of its weapons the following: a search sector, a search method, and a number of consecutive searches inside the sector before searching out of the sector. The unit is given a complete set of orders which includes its tactics, dictating its movement and firing actions.

An element type is the defining characteristic of a unit. In addition to weapon types, sensor types, and a load of ammunition, each element has dimensions, movement rates and mobility characteristics, a laser reflectivity coefficient, a detectable radius, a thermal contrast, an optical contrast, and a range of awareness. The element is assigned to a target class, vulnerability class, a fire response class, and suppression thresholds based on the preceding characteristics.

Each of the weapons or targets used in the battle simulation has its own set of inputs. These inputs include: a separate range for each target, number of crew members required to fire, neutralization weight against weapon systems of the opposing force, an assessment time, and reload doctrine. For each weapon there is a table of ammunition preferences which depends on the target type. The aim, re-aim and reload times are input along with standard deviations for each time. Each target has a probability that troops will be killed when the vehicle is killed by a direct fire weapon. The user can input for each weapon a set of priority lists for firing on

recognition. This aspect of the C/T model's target selection methodology will be discussed in greater detail later. [Ref. 9: p. 3 ]

Target definition in the C/T model is based on data which is input prior to the simulation run. The inputs are processed and written to files which are used by the C/T model. The input data enables the unit orders, discussed previously, to be executed during the simulation.

3. **Target Value Assessment**

TVA is a complex process within the C/T model due to the methodology by which it is implemented in the target selection function. TVA depends on the unit orders and supplemental input data. Prior to the battle simulation, each unit is given a complete set of orders which includes, among several other items, its firing doctrine. Inherent in these orders is the commander's or user's evaluation of a target's usefulness or worth to the enemy. These unit orders which are instrumental to the TVA process are based on the commander's perception of the enemy's combat capabilities (i.e., his subjective opinion of a target's value). Another means of evaluating a target's worth is through the use of probability of hit/probability of kill (PH/PK) codes which generate probability data. The data are used to measure a weapon's effectiveness or worth against various targets. As a result of the interchangeability between weapons and targets prevalent within the C/T model, the probability data can be further employed to assess a target's value. In addition to PH/PK codes, target dimensions and concealment indices are generated to obtain the amount of critical dimension exposed of a target. These indices are used for calculation of detection and hit probabilities of each weapon system against the target. The results which are generated provide the commander or user a mechanism to confirm or alter the TVA portion of the unit orders. TVA and target priority processes within C/T are closely related. The interaction of these two processes can be described in terms of the role of target acquisition in the target selection function. Therefore, certain aspects of the target acquisition methodology in the C/T model will be presented prior to discussing the target priority and target selection and engagement processes. [Ref. 9: p. 2]

The C/T model, like the two preceding models, utilizes the Night Vision and Electro-Optical Laboratories (NVEOL) detection model for its target acquisition. A prerequisite for target selection and engagement within the C/T model, as was the case with the previously discussed combat models, is that the target must be acquired. However, the C/T uses minimum level of discriminant (MLD) as opposed to the

potential target list employed by the Janus models. There are three MLD's (recognition, aim point, and detection) which represent the different levels of target discrimination or acquisition. Recognition is the highest MLD followed by aim point and detection. The target acquisition process impacts on C/T's target selection and engagement process. Prior to discussing target selection and engagement in the C/T model, it is useful to describe its priority schemes. [Ref. 10]

**4. Target Priority**

C/T target priorities are established by the user prior to the battle simulation run. The user can input a set of priority lists (one, two, or three) for each weapon which are based on target classes (e.g., BMP - 1st priority, Tank - 2nd priority, and Infantryman - 3rd priority). The target classes are also determined by the user during the initialization phase of the battle simulation. Once the priority lists have been input, targets are specified by element type and according to range and aspect boundaries. The importance of the target acquisition model to the overall target selection function of C/T is also evidenced within the model's target priority scheme.

C/T target acquisition (Primary Executive Routine) employes Ground Weapon Crew(s) and Commanders (Executive Routine) to provide additional considerations for prioritizing direct fire targets. The following two tables extracted from "Target Acquisition (TA) in Carmonette/TRASANA (C/T)" illustrate these considerations [Ref. 10: pp. 15-16].

TABLE 7

GENERATE THREE QUEUES AND THEIR CARDINALITY

* Viable enemy battlefield targets
* Enemy targets in Field of Regard (FOR) sector for which line of sight (LOS) exists but not within sensor Wide Field of View (WFOV)
* Enemy targets within sensor WFOV and LOS exists

TABLE 8

EXTRACT SEARCH METHODOLOGY (M)*

* M-ONE

  Seek targets in sensor WFOV

* M-TWO

  Seek targets known to be firing at me

  Seek targets in sensor WFOV

* M-THREE

  Seek targets known to be firing at me

  Seek targets known to be firing

  Seek targets in sensor WFOV

* M-FOUR

  Similar to M-TWO but do not engage

* M-FIVE

  Similar to M-THREE but do not engage

It is evident from these two tables that certain factors are instrumental to prioritizing targets. LOS prevails as key factor since a direct firer would experience a great deal of difficulty attempting to engage a target he could not see. The battlefield must also be divided into sectors to facilitate identifying targets of military worth, thus making a target's relationship within a specified field of view critical to its prioritization. In accordance with the guidelines outlined in Table 7, the highest priority will be assigned to the target that is not only in the direct firer's WFOV but also within his LOS. The search methods illustrated in Table 8 further depict the importance of dividing the battlefield into sectors. Additionally, the concept of assessing the target's firing status is introduced. A firing target poses a greater threat to a direct firer and hence warrants a higher priority than one that is not firing. C/T utilizes the aforementioned target priority considerations and combines them with additional requirements and the end result is the basis for the model's target selection and engagement procedures. A decision table is derived by consolidating these requirements and will be discussed in the ensuing section.

### 5. Target Selection and Engagement

The Target Priority Engagement/Decision Table (TLMN) - for Direct Fire Only is the mechanism by which targets are selected and engaged by direct firers within the C/T model. It is important to reiterate the fact that these targets must be acquired in order to qualify as candidates for selection and engagement. Additionally, the direct firer conducting target acquisition must be executing a unit order with the priority lists discussed in the preceding section before a target can be considered for selection and engagement. In conjunction with the preceding requirements, two additional requirements must also be met to ensure a target's eligibility for selection and engagement. First, the target class (e.g., tank classes - light, medium, or heavy armored) of the selected target must be on one of the three designated priority lists and also be discriminated at one of the following three MLD's: recognition, aim point, or detection. Second, the slant range from observer to target must be greater than or equal to the minimum range to the firer and less than or equal to the maximum range to the firer thus creating a range band in which the target must be located for selection eligibility. Once these criteria have been satisfied, a target can be selected and engaged in accordance with the following procedures [Ref. 11: p. 35-1].

The Decision Making Process for direct firers is as follows:

A. If the selected target is a first priority target (regardless of enemy intelligence information) and range constraints are satisfied,

engage the target immediately.

B. Discriminated or selected target is on a priority list and satisfies range requirements; but if it is not on priority list 1, then it is retained for future consideration (i.e., it is placed in the Engagement Target Queue (ETQ)).

C. If the discriminated target is not engageable (i.e., range constraints not satisfied), then only intelligence information is retained.

D. If selected target is in the ETQ (i.e., target class is on priority list 2 or 3 and range constraints have been satisfied) and no targets are remaining within sensor field of view (FOV), then the target in ETQ whose target class is nearest the top position of the selected priority list will be engaged. Note: all targets on priority list 2 must be exhausted prior to selecting targets from priority list 3. If there is a tie (i.e., two or more targets have the same priority list and class), then engage the target that is nearest the firer.

E. Weapon crews will cease search activity when time utilized exceeds the time required to search his sector of responsibility.

The target selection and engagement procedures of the C/T model build on each of the preceding processes and further emphasize the instrumentality of target acquisition to the target selection function.

## D. SIMULATION OF TACTICAL ALTERNATIVE RESPONSES (STAR)

### 1. Model Description

The STAR combat model is a discrete, event-step, high resolution, airland combat simulation developed at the Naval Postgraduate School (NPS), by students and faculty members, during the 1977-1979 time period. The original research and development was sponsored by HQ TRADOC. In July 1980, the development and maintenance of the STAR model was given to the TRADOC Research Element, Monterey (TREM) with continued assistance from the Naval Postgraduate School faculty and students.

The model is written in the Simscript II.5 computer language. STAR was not built for a specific cost operational and effectiveness study nor for any other specific study [Ref. 12: p. 1].

STAR models combat at the individual fighting system level. The entity, attribute, and set structure of SIMSCRIPT is used to represent the organization of fighting elements into combat units and will be further discussed as part of the target definition subsection. All actions, combat, and weapons effects are modeled at the fighting element level. Pop up tactics are also played. Aircraft may be engaged by either air defense or ground direct fire systems. Dismounted infantry is modeled at the individual soldier level and may be played either mounted or dismounted. Mounted soldiers dismount upon arriving at a defensive position, or at a dismount point in the assault. The soldiers actions, alternately rushing and taking cover while under firer, are explicitly modeled. Minefields and tank ditches are represented. The model runs on either digitized terrain data or an NPS developed continuous functional terrain model. Target acquisition is modeled using the NVEOL sensor model. [Ref. 12: p. 1]

STAR is an event-step, as opposed to a time-step, simulation which means that progression of the battle is determined by the completion of an event rather than the passage of a certain amount of time. Principal events of the STAR model are STEP.TIME, DETECT, TARGET.SELECT, FIRE, and IMPACT. These events perform the following functions respectively: generates times to detect targets, adds detected targets to list, selects targets and schedules fire, starts round(s) on way to target, and assesses and records results of round(s).

Another noteworthy characteristic of the STAR model is the fact that it distinguishes between the four different kinds of kills [Ref. 13: pp. 2-3]. This aspect of the model will also be further addressed in the target definition subsection.

### 2. Target Definition

The elements played (the Simscript entities) represent individual fighting systems: tanks, APC, individual soldiers, etc. Entities denote objects of a system (i.e., targets, for the purpose of this study) and attributes provide their characteristics. Each of these entities is described or defined in terms of 120 attributes which identify that particular entity in detail. A partial list of the attributes used to define targets in the STAR model follows [Ref. 13: p. 8].

TABLE 9

28 ATTRIBUTES FOR EACH ELEMENT

| | |
|---|---|
| Name | Color |
| System Type | Brigade |
| Weapon Type | Battalion |
| Vehicle Type | Company |
| Defilade | Platoon |
| X | Selection |
| Y | Alive or Dead |
| Z | Mobility Damage |
| Speed | Firepower Damage |
| Direction | # Times Shot at |
| Pop up | # Times Hit |
| Radar | # Times Fired |
| 4 Ammo Counts | Search Direction |
| Reload Status | Sector Width |

The above listed and the remaining 92 attributes are assigned to system and weapon types (targets) at the discretion of the user. After a target has been defined in terms of its characteristics, it is further defined with regard to its movement capabilities.

Target or system and weapon type movement within the STAR model is represented by movement decision logic which is based on two distinct criteria:

1. Range to enemy force, or
2. Combination of friendly attrition level and Red/Blue force ratio.

The user inputs values into the global array Table to implement the movement decision logic for targets. The following is a list of user inputs [Ref. 13: p. 9]:

1. Sys.type/Wpn.type he wants to monitor, up to a total of 6,
2. The range at which each system will move,

3. The 0/1 value indicating if a monitored system is restricted,
4. The range at which the entire unit will move,
5. Range within which Force Ratio is calculated, and
6. Range beyond which nothing happens.

The following table indicates how the first 4 columns of data for a particular maneuver unit might appear [Ref. 13: p. 10].

TABLE 10
MOVEMENT DECISION LOGIC

| Sys Type | Wpn Type | Range | Restricted? |
|---|---|---|---|
| 1 | 1 | 800 | 1 |
| 1 | 2 | 800 | 1 |
| 2 | 3 | 1000 | 0 |
| 2 | 4 | 1000 | 0 |
| 3 | 6 | 0 | 0 |
| 5 | 1 | 1200 | 0 |
| 3000 | 2500 | 800 | 1 |

The first 6 rows of the Table 10 data provide information about individual systems or targets. The 7th row contains information about the entire maneuver unit or target. The 1st row of Table 10 refers to Sys.Type 1, Wpn.Type 1 (target 1) which for the purposes of this illustration is assumed to be a BMP. Column 3 of row 1 specifies that if the enemy (direct firer of the opposing force) closes to within 800 meters of the maneuver unit, the BMP's will request to move. The user has specified in Column 4 that BMP's are a restricted system (which means permission must be granted by higher headquarters before any BMP's in this maneuver unit are allowed to move to subsequent defensive positions). Rows 2 thru 6 can be interpreted in the same manner as 1. However, the 7th row provides information concerning the entire maneuver unit:

- Column 1 specifies that if the unit of direct firers is not within 3000 meters of the maneuver unit, the unit will not move regardless of attrition level.

- Column 2 specifies that all units of direct firers within 2500 meters of the maneuver unit constitute the red elements in force ratio calculations.
- Column 3 specifies that if the unit of direct firers closes to within 800 meters of the maneuver unit, the unit will request to move.
- Column 4 specifies unit must have permission to move.

Attrition levels, force ratios, and ranges are all input by the user. These parameters are instrumental to the movement phase of the target definition process. Additionally, the impact of these parameters on the overall target selection function will be evidenced throughout the remainder of this section.

The STAR model also incorporates the four different kinds of kills (mobility, firepower, mobility and firepower, and catastrophic) into its target definition process. In a catastrophic kill there is serious damage -- perhaps the turret is blown off or the tank is on fire -- and it is obvious to all combatants that the target is dead. A tank that is mobility and firepower killed cannot engage, but it is not so obvious to other combatants that it is out of the battle. In STAR, mobility- and firepower-killed entities continue to be selectable targets for a user-input length of time (traditionally 60 seconds). Once a target has been inflicted with one of the aforementioned types of kills, its worth or value changes. These changes and other means by which target value assessment (TVA) is achieved within the STAR model will be discussed in the following section. [Ref. 12: p. 4]

### 3. Target Value Assessment

The extensive list of attributes availed to the user within the STAR model enables him to not only define targets, but to assign them a value or worth as well. This transpires during the initialization phase of the battle simulation. As a result of the similarities between the target definition and the TVA processes at the outset of the simulation, the impact of the TVA process in the STAR model does not become readily apparent until the target selection and engagement process commences. Once targets are selected and engaged, their assessed values are dependent on two factors. First, the priority given the target by the user. This factor will be discussed in the ensuing subsection. Secondly, the damage level or type of kill incurred by a target during the battle simulation which will be the item of interest within this subsection.

As stated above, the four types of kills are: mobility, firepower, mobility and firepower, and catastrophic. Each type of kill has a different worth or damage level associated with it. When a target is hit by a round, it is usually damaged to some

degree (i.e., one of the four kill types) thus causing the target's worth to change. For example, a mobility-killed vehicle or target that cannot move but certainly is capable of engaging opposing forces has a greater value than a firepower-killed vehicle which cannot fire but continues to move with the formation as a viable target. Further, a catastrophically killed target has the highest damage level and, correspondingly, the lowest value assessed to it.

The methodology implemented by the STAR model to determine damage levels or target worth during the battle is quite complex. The algorithmic procedures employed to derive these damage levels are not of major concern in this study. An aspect of the TVA process that merits discussion is the concept of Alpha. Alpha is the percent of previously incurred damage which is considered in assessing the current hit and is instrumental to the TVA process. The user selects how much of the damage is to be carried forward (i.e., Alpha value chosen), which in turn directly impacts on the TVA process. Increasing Alpha increases the probability that a target gets both mobility and firepower killed on the second and subsequent rounds. Nevertheless, Alpha does not affect the probability that a target is catastrophically killed since that is assumed to be independent, round to round. Table 11 shows the probabilities associated with several different Alpha values as succeeding rounds are fired [Ref. 13: p. 14].

The Alpha concept's interaction with the four kinds of kills provides a means of assessing a target's value during the course of the simulated battle and further illustrates the importance of the four kill types to the overall target selection function.

#### 4. Target Priority

Targets are prioritized within the STAR combat model by user inputs. These inputs are in the form of lists which prioritize all targets which might be engaged by a particular combatant. This implementation allows the user to define a different selection criteria or prioritization for each individual combatant.

In the STAR priority list, an engagement is described by three factors:

1. The target weapon system type,
2. The range to the target (considered in several range bands), and
3. The ammunition type to be used.

For each type of engagement that the user decides to allow for this type of firer, the priority list for this firer will contain the three factors defining the engagement along

TABLE 11

PROBABILITIES FOR SEVERAL ALPHA'S

| 2D | ALPHA | | | | | | |
|---|---|---|---|---|---|---|---|
| Hit | 0.0 | 0.05 | 0.10 | 0.25 | 0.50 | 0.75 | 1.0 |
| K | .10 | .10 | .10 | .10 | .10 | .10 | .10 |
| MF | .20 | .21 | .22 | .26 | .32 | .38. | .44 |
| F | .15 | .15 | .15 | .15. | .15 | .16 | .16 |
| M | .10 | .10 | .10 | .10 | .10 | .10 | .10 |
| NK | .45 | .44 | .43 | .39 | .33 | .26 | .20 |

| 3D | ALPHA | | | | | | |
|---|---|---|---|---|---|---|---|
| Hit | 0.0 | 0.05 | 0.10 | 0.25 | 0.50 | 0.75 | 1.0 |
| K | .10 | .10 | .10 | .10 | .10 | .10 | .10 |
| MF | .20 | .22 | .24 | .30 | .40 | .51. | .61 |
| F | .15 | .15 | .15 | .14. | .14 | .13 | .12 |
| M | .10 | .10 | .10 | .09 | .09 | .08 | .08 |
| NK | .45 | .43 | .41 | .36 | .27 | .18 | .09 |

| 4D | ALPHA | | | | | | |
|---|---|---|---|---|---|---|---|
| Hit | 0.0 | 0.05 | 0.10 | 0.25 | 0.50 | 0.75 | 1.0 |
| K | .10 | .10 | .10 | .10 | .10 | .10 | .10 |
| MF | .20 | .23 | .25 | .33 | .46 | .59. | .72 |
| F | .15 | .15 | .14 | .13. | .12 | .10 | .09 |
| M | .10 | .10 | .09 | .09 | .07 | .06 | .05 |
| NK | .45 | .43 | .41 | .34 | .25 | .14 | .04 |

Note: NK = No Kill

with a user input priority number which ranks the engagement against other possible engagements.

When a SELECT event occurs for a combatant, the detected list for the combatant is compared to his priority list. Any enemy for which the target type and range band match an entry in the list is thus assigned a priority number and an ammunition type. The highest priority target from the detected list is chosen for engagement (if the required ammunition is available). [Ref. 13: pp. 14 and 15]

The STAR high-resolution combat simulation model explicitly allows for several kinds of coordination behavior whenever a simulated combatant selects a target to be engaged. STAR currently provides fourteen distinct target selection coordination tactics. Each firing weapon system type is associated with one of these tactics by user inputs. The fourteen target coordination tactics are as follows:

1. Attempt to engage your platoon leader's target. Failing this, search your platoon to determine which of your targets are not being engaged by another platoon member. From this reduced set, engage your highest priority target. If all targets are engaged, engage your highest priority target using your user specified alternate ammunition type.

2. Attempt to engage your platoon leader's target. Failing this, search your platoon to determine which of your targets are not being engaged by another platoon member. From this reduced set, engage your highest priority target. If all targets are engaged, engage your highest priority target anyway.

3. Attempt to engage your platoon leader's target. Failing this, search your platoon to determine which of your targets are not being engaged by another platoon member. From this reduced set, engage your highest priority target. If all targets are engaged, do not engage any target.

4. Same as 1., except company is searched instead of platoon.

5. Same as 2., except company is searched instead of platoon.

6. Same as 3., except company is searched instead of platoon.

7. Attempt to engage your platoon leader's target. Failing this, engage your highest priority target regardless of its engagement status by others.

8. - 14. These tactics are identical to tactics 1. - 7. except that no attempt is made to engage the platoon leader's target.

Thus tactics 1 through 7 attempt a platoon leader handoff as the primary choice for target selection. Tactics 8 through 14 move directly to an evaluation of each target in the selector's list of acquired targets. The following table summarizes the preceding rules of engagement [Ref. 13: p. 7].

TABLE 12

ENGAGEMENT RULES

1. Platoon leader handoff
2. Highest priority target
3. Highest priority target unengaged by platoon member, else highest priority target
4. Highest priority target unengaged by a company member, else highest priority target (engage with automatic weapon fire only).
5. Highest priority target unengaged by a platoon member, else do not engage.

An example of an array of input data further illustrates the target selection and engagement process within the STAR model. Table 13 depicts an array for a system type 2 and weapon type 3, is shown in Table 13 [Ref. 13: pp. 42-43].

TABLE 13

TARGET SELECTION ARRAY

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 - 1000 | meters | 1 | 7 | 3 | 1 | 2 | 8 | 1 | 3 | 2 | 8 | 2 | 1 |
| 1000 - 2000 | meters | 1 | 7 | 11 | 1 | 2 | 8 | 12 | 1 | 2 | 8 | 13 | 3 |
| > 2000 | meters | 1 | 7 | 21 | 1 | 2 | 8 | 22 | 1 | | | | |

The first row represents the 0-1000 m range band and has 3 blocks of 4 numbers. The first 4 numbers indicate that system type 1, weapon type 7 has a priority 3 using ammunition type 1 within this range band. Thus numbers are read in the following order:

- System type of target,
- Weapon type of target,
- Priority of this target, and
- Ammunition type to be used against this target.

Further, within system or weapon types, if more that one priority is to be assigned within a range band, the blocks of 4 numbers should be adjacent and the priorities increasing to the right.

If a firer is not capable of engaging targets within a specified range band, a row of 4 zeros (0,0,0,0) should be input for that range band.

In the actual target selection process, each potential target in the element's detected list is evaluated with respect to its priority. Table 13 illustrates that targets in the 1000-2000 meter range band were assigned priorities 11, 12, and 13. Since the lowest numerical priority is selected (with the closest target selected for equal priority), range band 0-1000 will always have priority over band 1000-2000. Range becomes the discriminator when two or more targets within the same range band are of the same priority (i.e., the target closest to the firer will be selected for engagement). If, for example, it is desired to have the 2000-3000 range band as highest priority, the user assigns the lowest numerical values of priority to target/ammo types in that range band [Ref. 13: pp. 42-43].

A key feature of the STAR model's target selection and engagement process is the user's capability to pair weapon systems and targets within the appropriate range bands. For example, pairing a TOW missile system against a target located within the 0-1000 m range band is useless since the TOW's maximum and minimum effective ranges do not fall within this range band. The STAR model provides the user with a means to ensure the compatibility between system and weapon types of targets and firers (i.e, targets are located within range bands congruent to the engagement capabilities of the direct fire system and weapon types).

# IV. ANALYSIS

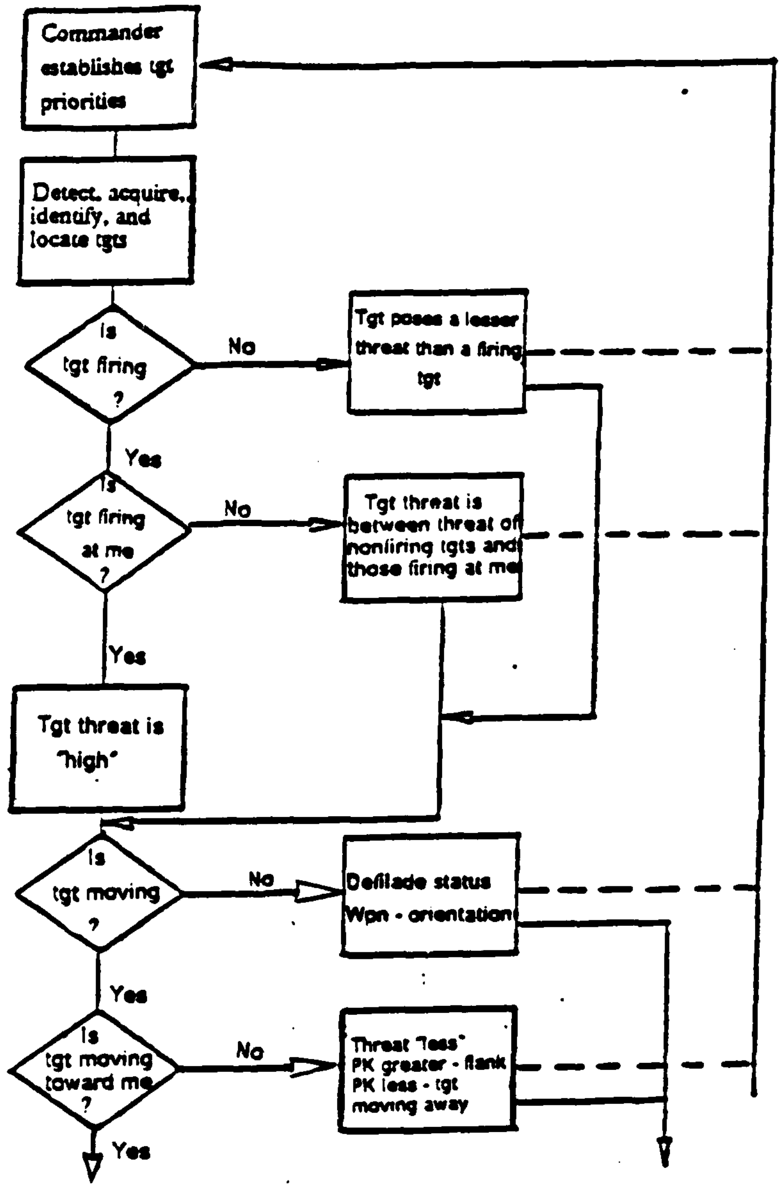
## A. BACKGROUND

In the preceding chapter, four high resolution combat models were discussed. An overview of each model was presented followed by an in-depth discussion with regard to its "target selection function". As previously stated, the "target selection function" is comprised of four processes: target definition, target value assessment (TVA), target priority schemes, and target selection and engagement. The features of the target selection methodologies of these four models will be discussed, compared, and contrasted in the ensuing analysis. Doctrine dictates how firers should select targets in actual combat. Assuming doctrine is followed in combat, a comparison of each model's target selection methodology to that of doctrine should provide insight into the models fidelity.

## B. COMPARISON OF MODELS TO DOCTRINE

The "Combined Arms Operations Volume Two" [Ref. 1] currently used by the Combined Arms Staff School at Fort Leavenworth, Kansas and DARCOM-P 706-101 [Ref. 2] were the two sources of documentation used in this study to provide information on the doctrinal approach to target selection. Doctrinal documentation on target selection proved to be difficult to obtain as were general studies on this subject. Further, doctrine pertaining to target selection is highly subjective and judgmental, resulting in constant reassessments, by military leaders, of what a direct firer should consider most important in selecting a target. As previously stated, commanders and others in leadership positions attempt to influence the soldier in accordance with these doctrinal guidelines.

To facilitate the comparison of the four target selection algorithms to doctrine, five flowcharts were developed. The first flowchart depicts "doctrinal" target selection, and the succeeding four those of the four models. The doctrinal flowchart was based on the aforementioned references with subjective interpretation by the author. The flowcharts for the models conform to the target selection algorithm descriptions presented in the preceding chapter. A matrix (Figure 4.6) is provided (following the flowcharts) to highlight and consolidate the salient features of each flowchart.




Note: - - - indicates possible changes.

Figure 4.1 Doctrinal Flowchart.



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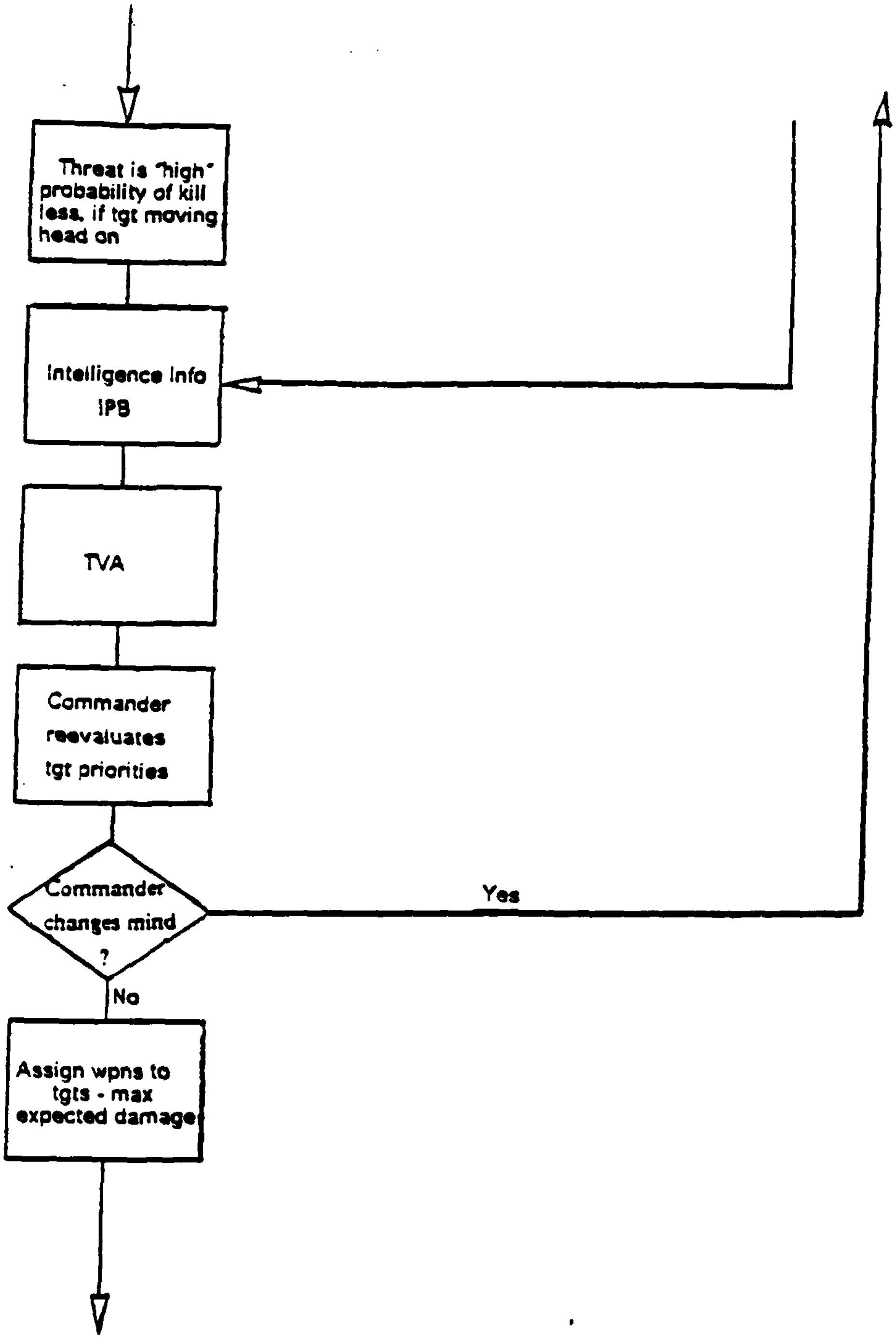


Figure 4.1 Doctrinal Flowchart (cont'd).

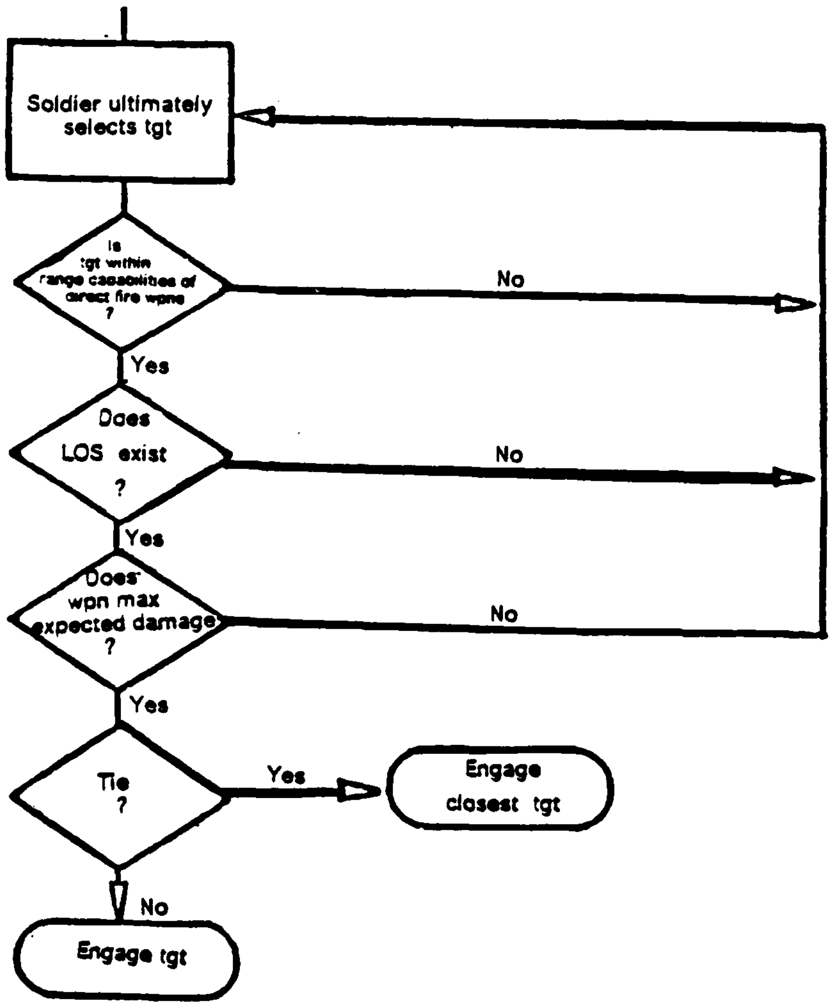


Figure 4.1 Doctrinal Flowchart (cont'd).

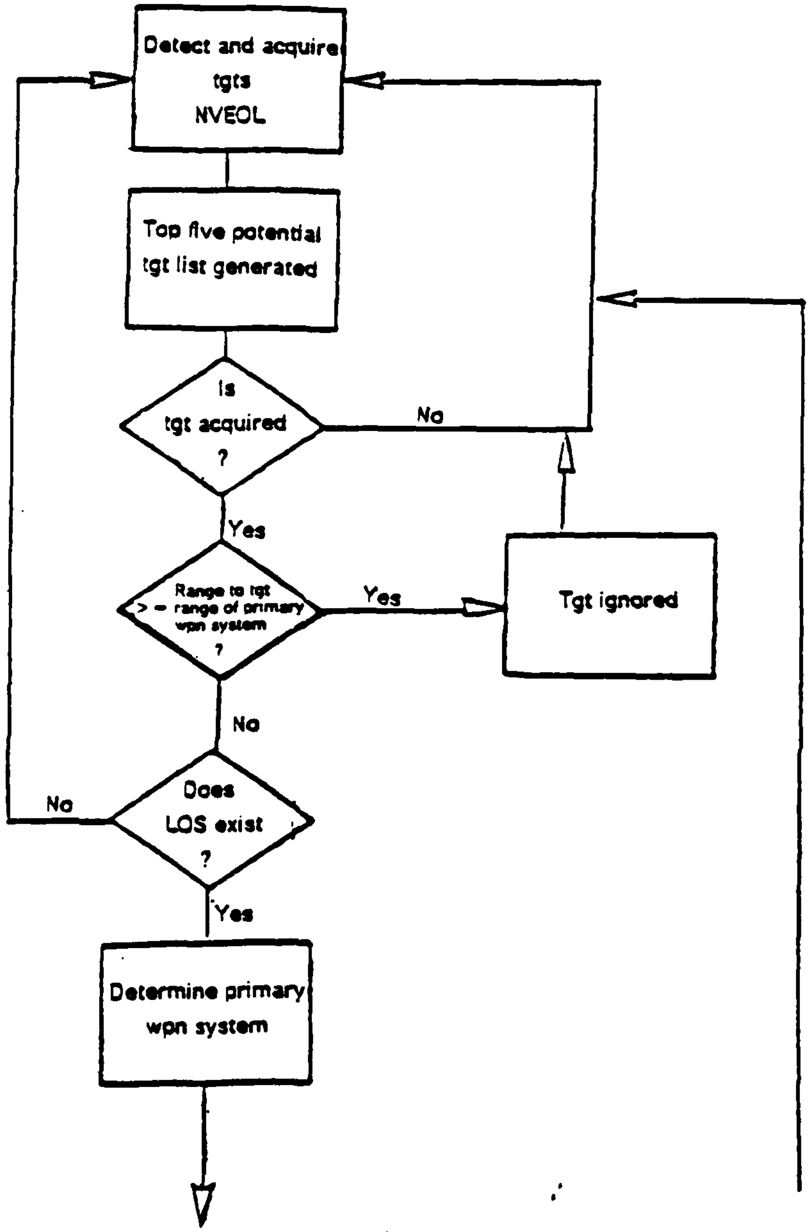


Figure 4.2 Janus(T) Flowchart.

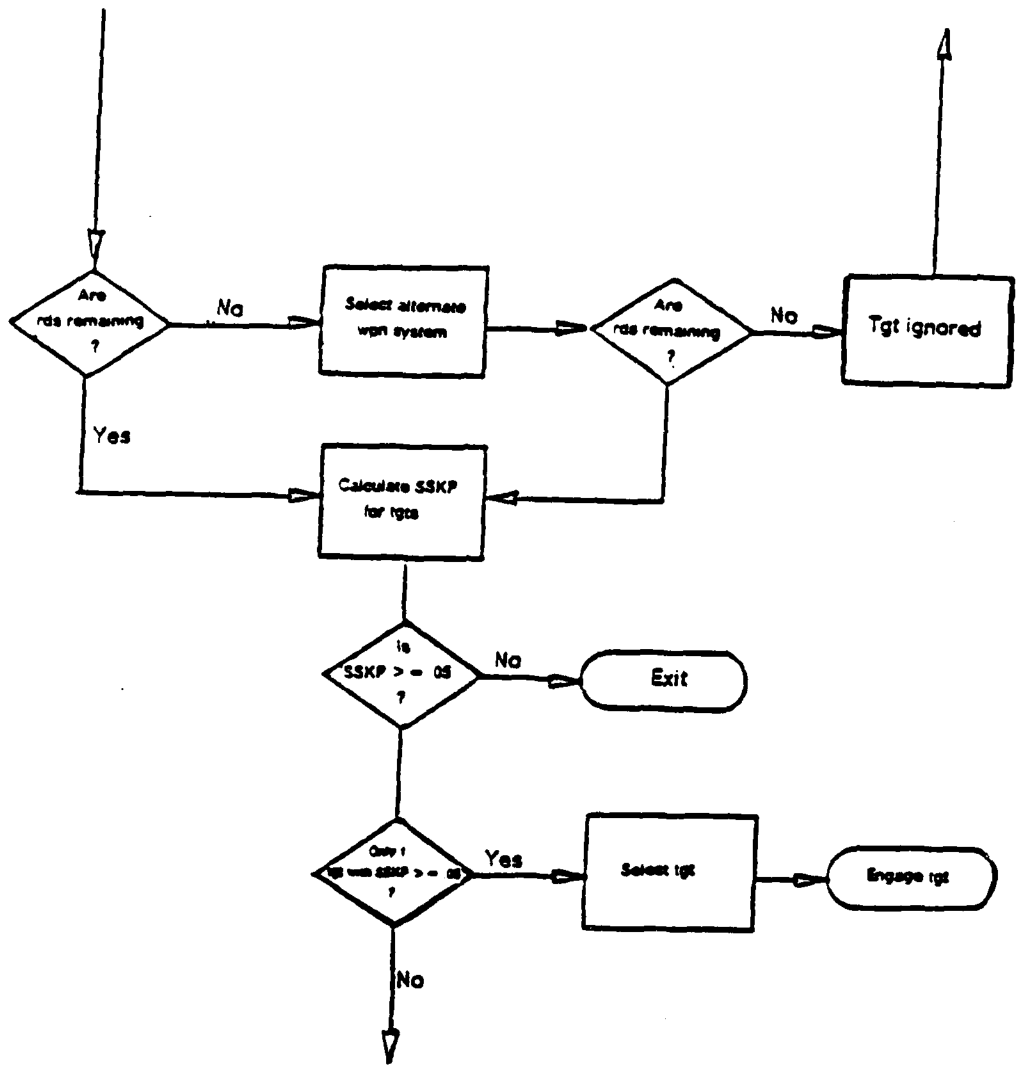


Figure 4.2 Janus(T) Flowchart (cont'd).

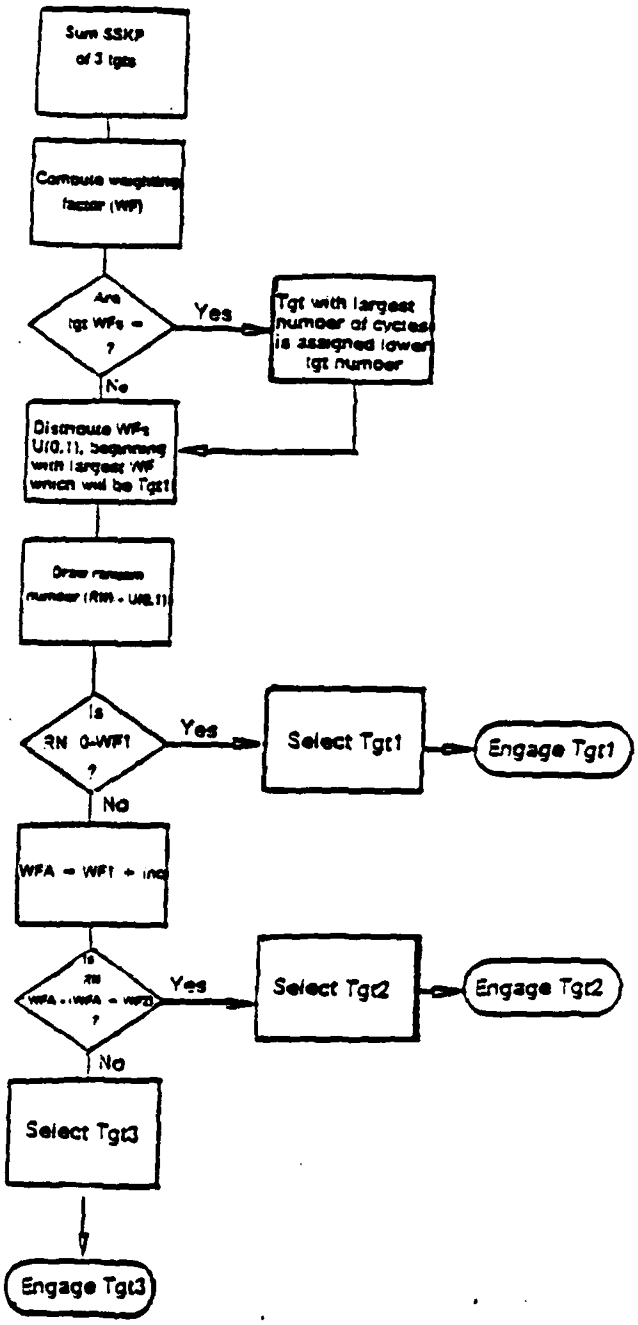


Figure 4.2 Janus(T) Flowchart (cont'd).

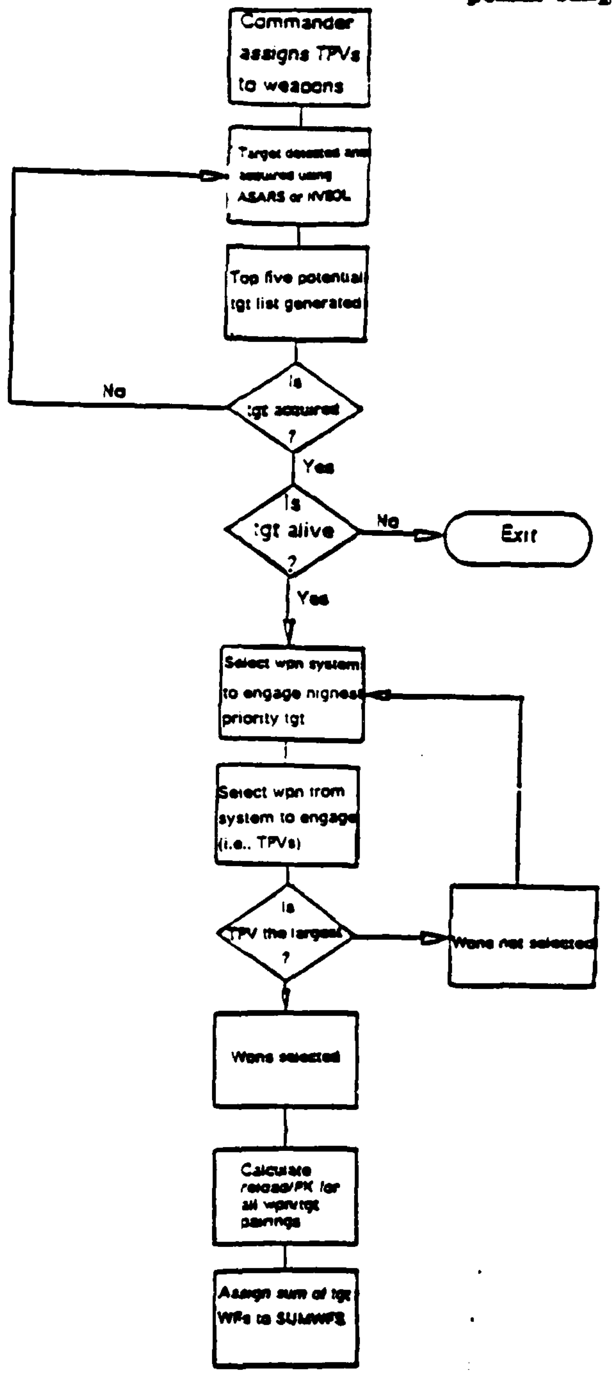


Figure 4.3 Janus(L) Flowchart.

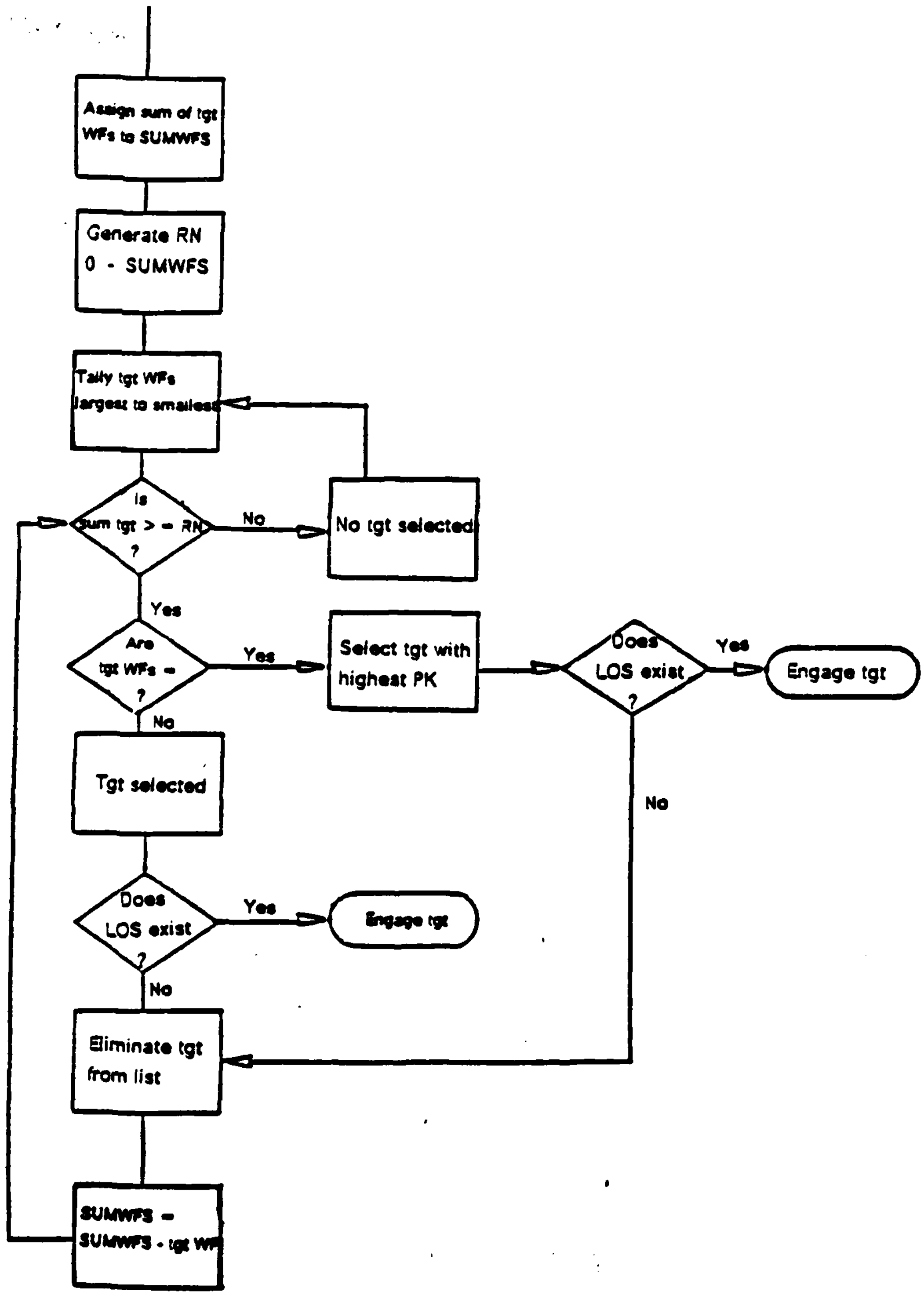


Figure 4.3 Janus(*L*) Flowchart (cont'd).

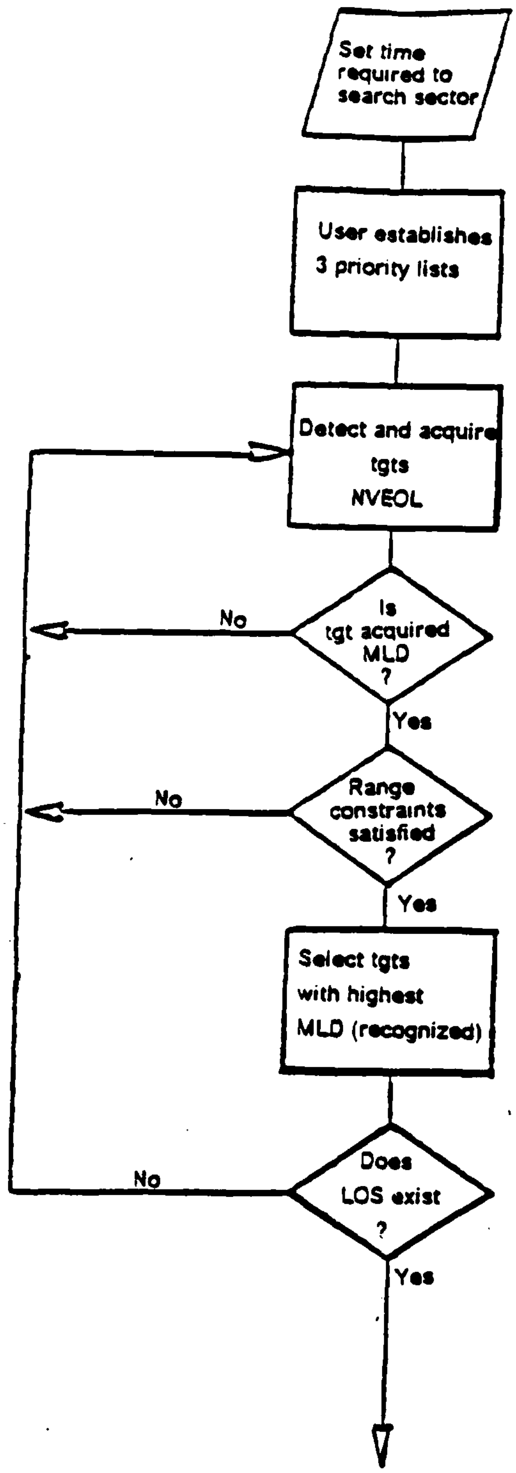


Figure 4.4 Carmonette Flowchart.

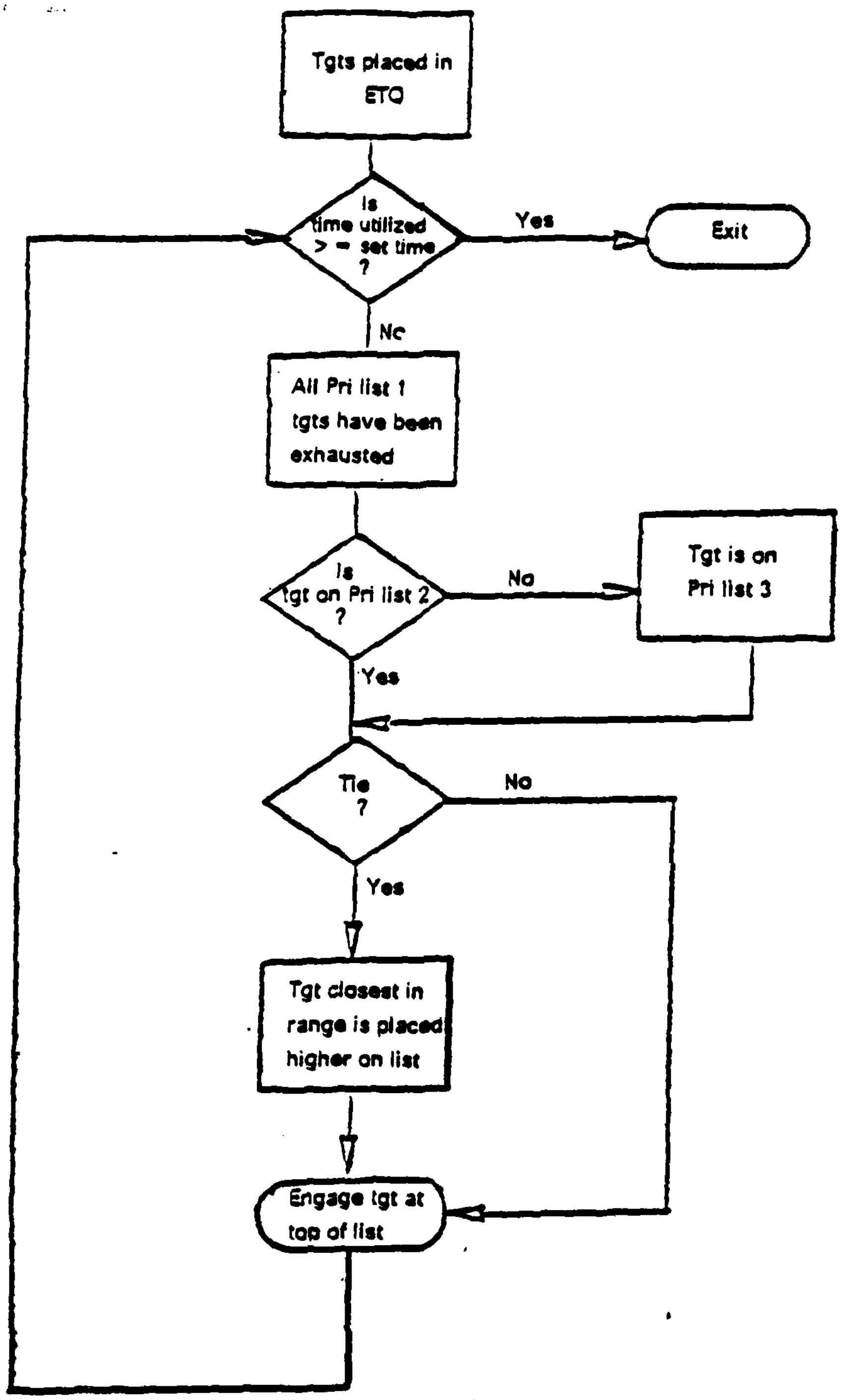


Figure 4.4 Carmonette Flowchart (cont'd).

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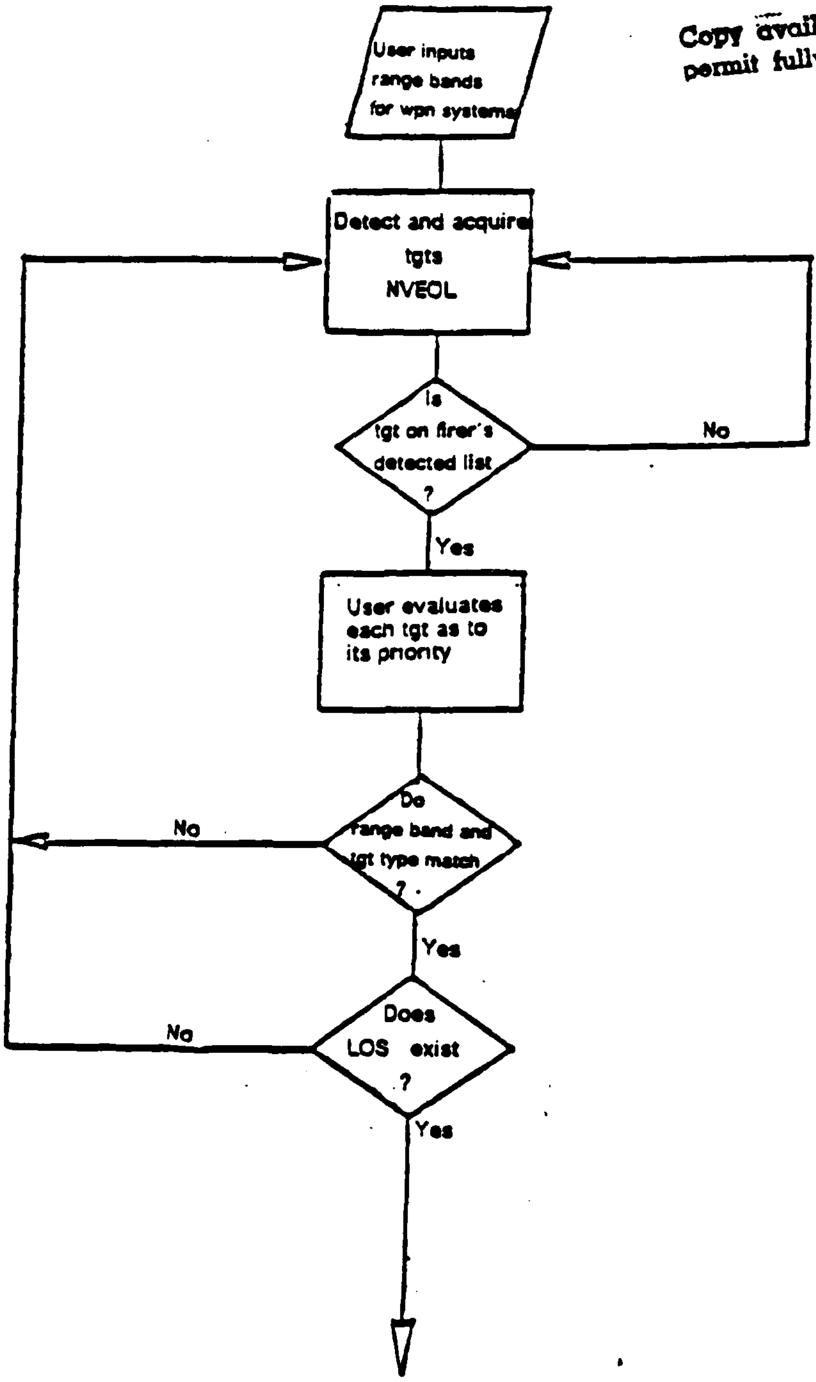


Figure 4.5 STAR Flowchart.

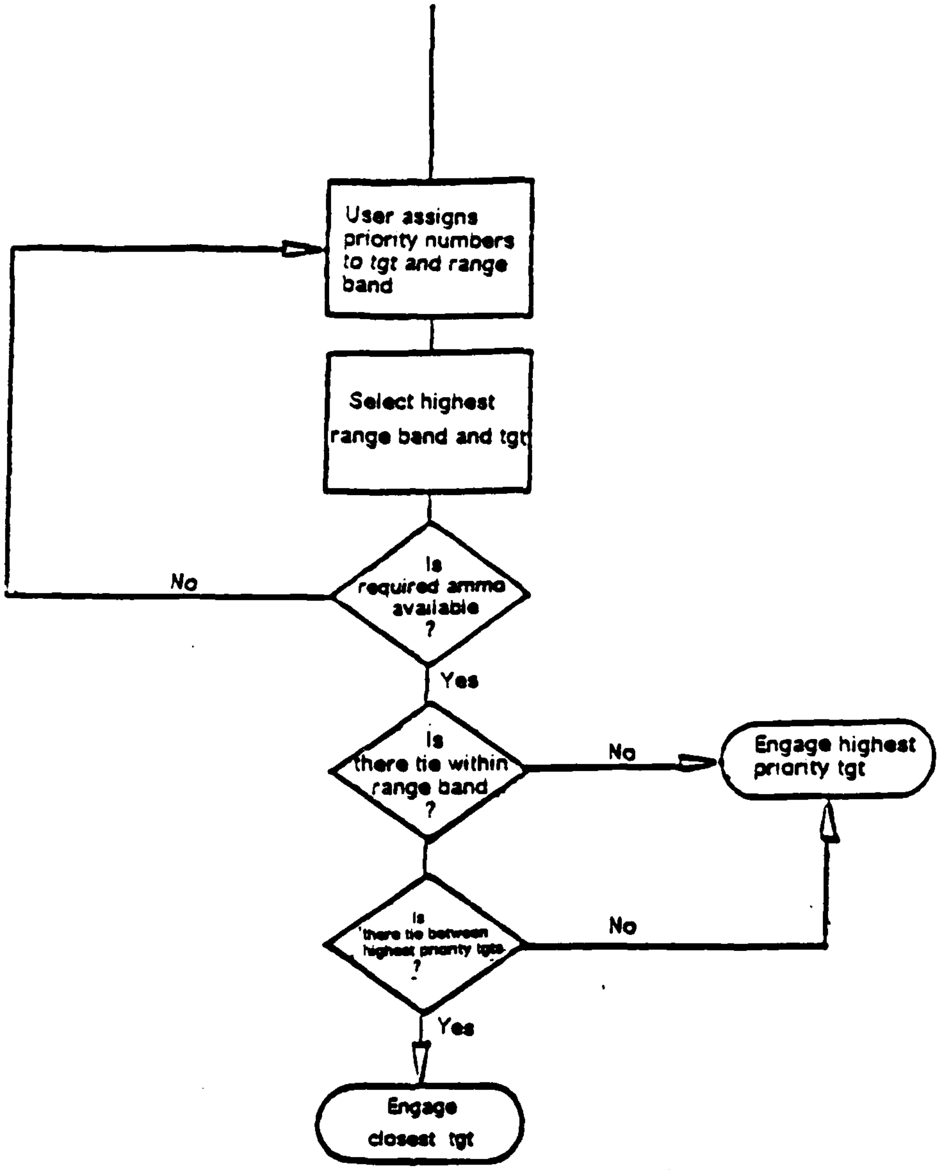


Figure 4.5 STAR Flowchart (cont'd).

| | TVA | Target Priorities | Target Selection and Engagement |
|---|---|---|---|
| Doctrine | Detect, acquire, identify, and locate targets.<br>Gather and analyze intelligence information.<br>Threat evaluation | Established at discretion of the commander.<br>Commander assigns weapons to targets that will maximize total expected damage. | Commander influences soldier. However, soldier has ultimate responsibility of selecting target. |
| Janus(T) | NVEOL detection model.<br>PK/PH tables. | Pre-game user inputs | Weighting factor |
| Janus(L) | NVEOL or ASARS detection model.<br>PK/PH tables. | Pre-game user inputs | Weighting factor |
| Carmonette | NVEOL detection model.<br>PK/PH tables.<br>Retains intelligence information on targets. | Hard-wired unit orders | Range bands |
| STAR | NVEOL detection model.<br>PK/PH tables.<br>Alpha concept. | Pre-game user inputs | Range bands |

Figure 4.6 A Comparison of Models to Doctrine.

The flowcharts and matrix indicate a direct correlation between the models' target selection methodologies and that of doctrine. The models all have mechanisms in place to implement the important factors or rules of doctrine TVA, target prioritization, and target selection and engagement.

## C. MODEL COMPARISON

Having compared the models' target selection methodologies to that suggested by doctrine, these methodologies will now be further contrasted with each other. A scenario will be described and applied to each model's target selection algorithm. This should demonstrate each model's target selection process. Due to differences among the models, a wide range of scenario data was established. This portion of the analysis deals only with actual target selection. TVA and target priority, processes which impact on the final selection of a target, will be discussed later. A brief synopsis of the scenario conditions is given in the description of each model's target selection process.

A Bradley Fighting Vehicle (M2) system engaged in combat is confronted with three targets (a BMP, ZSU, and T-72) in its FOV from which one must be selected for initial engagement. The M2 is equipped with the following direct fire weapons: 50 Caliber machinegun, 25mm cannon, and TOW anti-tank missile. This simple scenario includes the requisite constituents to facilitate a detailed depiction of each model's target selection process. The following tables display the data needed in applying the scenario conditions to each model's target selection methodology:

TABLE 14
TARGET SCENARIO DATA

| Target | BMP | ZSU | T-72 |
|---|---|---|---|
| Tgt Priority | 1 | 2 | 2 |
| System | Mounted Infantry | Air Defense | Tank |
| Tgt - Class | Light Armored Veh (tracked) | Antiaircraft Gun | Med-Tank |

TABLE 15
WEAPON SCENARIO DATA

| M2 Wpns | 50 Cal. | 25mm | TOW |
|---|---|---|---|
| Reload Time(secs) | 25 | 5 | 50 |
| Range(meters) | 1000 | 1500 | 2000 |
| Ammo type | HEAT | APDS | APDS |
| No. of Rds | 0 | 25 | 25 |
| PH | .8 | .5 | .25 |
| PK | .5 | .2 | .4 |
| Cycles | 2.5 | 4.5 | 3.9 |
| MLD | Recognized | Aim Point | Recognized |
| PL | 1 | 2 | 2 |
| PL position | 1 | 2 | 1 |

PL represents Priority List

The data listed under each of the three target column headings (BMP, ZSU, and T-72 or 50 Cal, 25mm, and TOW) pertain to that specific target or weapon.

1. **Janus(T)**

The weighting factor or probability of selecting each target will be calculated and further utilized to select a target. Prior to beginning the actual illustration, the following assumptions are made:

1. Firer has LOS to all targets;
2. Ammunition is available;
3. Range constraints are satisfied; and
4. Primary weapon system is chosen:
   - 50 Cal. fires at BMP,
   - 25mm fires at ZSU, and
   - TOW fires at T-72.

TABLE 16

JANUS(T) SCENARIO DATA

| Target | PH | PK | SSKP | Range | Cycles |
|---|---|---|---|---|---|
| BMP | .8 | .5 | .4 | 1000 | 2.5 |
| T-72 | .25 | .4 | .1 | 2000 | 3.9 |
| ZSU | .5 | .2 | .1 | 1500 | 4.5 |

The data in the above table was selected to illustrate the target selection methodology of Janus(T) and is not to be viewed as correct or close to either classified or unclassified data. The SSKP values for each target were calculated by multiplying the PH by PK for that particular target. The weighting factor assigned to each target is obtained by summing the SSKP's of each target and then dividing the individual target's SSKP by the total of this summation. The following depicts the weighting factors resulting from the application of scenario data:

$$\text{Sum of SSKPs} = 0.4 + 0.1 + 0.1 = 0.6. \qquad \text{(eqn 4.1)}$$

Once the targets and their corresponding intervals have been established, a U(0,1) random draw is used to determine which target is selected. For the purpose of this scenario application, assume the random number of 0.52 was drawn. This would result in the BMP being selected and engaged by the M2 system since 0.52 falls within the interval (0.0,0.667).

2. **Janus(L)**

The scenario conditions will be adapted to the Janus(L) model which also uses the weighting factor approach to target selection. Ascertaining the weapons with the highest target priority values is the first of three steps used to compute the weighting factors which are instrumental to ultimate selection of an engageable target. The second step is to acquire a numerical value for each target by dividing its PK by the direct fire weapon's reload time. Thirdly, the weighting factor for each target is computed by multiplying the target priority value by the numerical value associated with each target. The following assumptions and scenario data are provided to illustrate the aforementioned three steps and additional procedures which result in the selection of a target.

Assumptions:

1. LOS exists for all target and weapon combinations, and
2. Range requirements are satisfied.

TABLE 17
JANUS(L) SCENARIO DATA

| Wpn System (M2) | Targets | | | PK | Reload Time |
|---|---|---|---|---|---|
| | BMP | T-72 | ZSU | | |
| TOW | *9 | 1 | *10 | .4 | 5 |
| 25mm | 1 | *2 | 4 | .2 | 15 |
| 50 Cal. | *9 | 0 | 3 | .5 | 25 |

* indicates weapons with the highest target priority values for target heading that column

The first column of the above table depicts a M2 system with three weapons (TOW, 25mm, and 50 Cal.). The succeeding three columns represent three targets (BMP, T-72, and ZSU) and their corresponding target priority values (TPV). TPV are commander or user input numbers which represent the value of a particular weapon system being selected to engage the target heading that column. The last two columns list selected PK's and reload times for weapons assigned to the M2.

The first step of the process (selecting the highest priority values) results in selection of the following weapon/target combinations:

Now, the final target selection procedures will be discussed. A random number generator is used to attain a number uniformly distributed between zero and the sum of the weighting factors (0.0,SUMWFS). Subsequently, the individual target weighting factors are tallied in descending order until the summation is greater than or equal to the randomly generated number. The target corresponding to the weight factor used most recently to increment the summation is selected provided LOS exists. If LOS does not exist, the target is eliminated, and the process starts over.

A tie occurred between the weighting factors of the TOW/ZSU and 25mm/T-72. This tie must be resolved prior to tallying the weighting factors. Once again, ties are decided in favor of the weapon possessing the highest PK. Therefore, the weighting factor of the TOW/ZSU will be tallied before that of the 25mm/T-72 since the PK of the TOW (0.4) is greater than that of the 25mm (0.2). Based on the scenario data, the following target selection and engagement is generated:

$$SUMWFS = 0.34. \qquad \text{(eqn 4.12)}$$

Generate a random number between (0.0,0.34).
Assume the random number generated is 0.24.
Tally weighting factors (descending order) until the summation is greater than or equal to 0.24.

Revised weighting factors in descending order:

| Weapon | Weighting Factor |
|---|---|
| TOW/BMP | 0.18 |
| TOW/ZSU | 0.08 |
| 25mm/T-72 | 0.08. |

Tallying process:

$$0.18 < 0.24 \qquad \text{(eqn 4.13)}$$

$$0.18 + 0.08 = 0.26 > 0.24. \qquad \text{(eqn 4.14)}$$

The tallying process for selection of the first target is terminated since 0.26 is greater than 0.24, and the target selected is the ZSU which will be engaged by a TOW.

3. **Carmonette**

The following assumptions and scenario data in Table 5 are used to illustrate the Carmonette target selection process:

1. Slant range requirements are satisfied;
2. Firer has LOS to all targets; and
3. User input time constraints allow for all priority lists to be exhausted.

TABLE 18

CARMONETTE SCENARIO DATA

| Targets | MLD** | Range | Position on PL* |
|---|---|---|---|
| BMP - PL1 | Recognized | 1000 | 1 |
| ZSU - PL2 | Aim Point | 2000 | 2 |
| T-72 - PL2 | Recognized | 1500 | 1. |

*PL represents Priority List

**MLD represents Minimum Level of Discriminate

The BMP and T-72 are both discriminated at the highest level (recognized) which makes them initial candidates for selection. However, the BMP is a priority list 1 target; therefore, it is selected over the T-72 (priority list 2). In view of the fact that the BMP is the only target on priority list 1, it is engaged immediately. This decision rule applies to all first priority targets regardless of prior intelligence information.

The T-72 is on a priority list and satisfies the range requirements which results in its being placed in the engageable target queue (ETQ). The ZSU is also placed in the ETQ based on the same rationale. These two targets will remain in a holding state or queue until all of the first priority targets have been exhausted. Adapting the scenario data to Carmonette's target selection function resulted in both target's stay in the queue being short, since there was only one target on priority list 1.

The targets on priority list 2 are now considered for selection and engagement and must all be eliminated prior to moving to priority list 3. The T-72 is selected and engaged prior to the ZSU due to its MLD and position on the priority list.

To illustrate the decision making when ties occur, the scenario data are altered. Occurrence of a tie requires two or more targets of the same class to occupy the top positions of any given priority list. Accordingly, for the purpose of this illustrative example, assume that the ZSU is replaced by another T-72 (i.e., two targets of the medium tank class are at the top of the priority list). However, suppose all other data in the table row that used to contain the ZSU remain unchanged. Now, there are two targets of the same class which occupy the first and second positions on the same priority list. A tie of this nature is resolved by selecting the closest target. Therefore, the T-72 in position 1 is selected since it is closer to the firer (i.e., 1500 is less than 2000) and LOS exists.

4. **STAR**

Some of the codes applicable to the STAR model, coupled with pertinent scenario data, must be given prior to illustrating the STAR target selection process. The codes displayed in the following table were extracted from "Tactical Parameters and Input Requirements for the Ground Component of the STAR Combat Model" [Ref. 13: pp. 58 - 59].

TABLE 19
STAR SCENARIO DATA

| System | Weapon | Target | Pri | Ammo | Rds | Range |
|---|---|---|---|---|---|---|
| 1-Tanks | 7-125mm | T72 | 2 | 1-APDS | 25 | 2000 |
| 2-Mounted Infantry | 8-73mm | BMP | 1 | 2-HEAT | 0 | 1000 |
| 6-Air Defense | 9-23mm | ZSU | 2 | 1-APDS | 25 | 1500 |

*Pri represents Priority of Target

The target selection function of the STAR model utilizes an array of input data. This array consists of the following four user inputs:

1. System type of target,
2. Weapon type of target,
3. Priority of this target, and
4. Ammunition type to be used against this target.

The four user inputs are read in increasing order (1-4) and would result in the following individual arrays utilizing the scenario data:

T-72 1 7 2 1
BMP 2 8 1 2
ZSU 6 9 2 1.

The four numbers corresponding to the T-72 indicate: system type 1 (tanks), weapon type 7 (125mm), priority of target 2, and ammunition type 1 (APDS). The succeeding arrays are interpreted in the same manner. To provide consistency between models when using the scenario data, the priority values were chosen in accordance with the weighting factor values of the Janus models (i.e., priority 1 corresponds to the largest weighting factor). The actual input data is a consolidation of the individual arrays into one array which is preceded by a range band. The scenario input data would appear like this:

1000 - 2000 meters 1 7 2 1 2 8 1 3 6 9 2 1.

The range band brackets the targets based on their distance from the firer. For the purpose of this illustration, the direct firer weapon is assumed to be a TOW assigned to an M2 system. The absence of zeros (0 0 0 0) in the above array indicates that the firer can engage all three of the designated targets. The targets and range bands are selected by the highest priority which corresponds to the lowest numerical priority value. Since the priority values of 1 and 2 are within this range band, it would be the first one selected. Similarly, the BMP (priority 1) would be the target selected. However, ammunition is not available to engage the BMP. Moving to the highest priority target, a tie is revealed between the T-72 and ZSU. The target selection function within the STAR model resolves ties by selecting the target closest to the firer. Following this decision rule, the ZSU is selected (i.e., 1500 is less than 2000) and engaged since there is ammunition available.

### 5. Discussion

Application of the same scenario to the four models' target selection algorithms resulted in the selection of the BMP by Janus(T) and Carmonette while the ZSU was selected by Janus(L) and STAR. However, it is important to note that the BMP would have also been selected by STAR had ammunition been available. Do these results indicate inconsistencies between the models' target selection methods? The methods of each model must be further investigated to address this question.

The target selection methodologies of both Janus models utilize weighting factors to determine the selection and subsequent engagement of their respective targets. The primary differences between these two target selection schemes are the parameters used in computing the weighting factors and the user assigned target priority values of Janus(L). Janus(T) utilizes SSKP (PHxPK) divided by the sum of the SSKPs; whereas, Janus(L) derives its weighting factor from dividing a weapon's PK by its reload time. Each of these methods employs a random draw in order to select a target. The random draws are from uniform distributions. However, due to the various magnitudes assigned to the coefficients of the weighting factors, the uniform distribution over (0,SUMWFS) used within Janus(L) must be scaled down in order to achieve a uniform distribution compatible with the desired range. In both schemes, the comparison of a randomly drawn value to a scaled value is used to select a target. Despite the variation in the parameters used to ascertain scale factors, both approaches result in the target with the largest scale factor having the greatest probability of being selected. This could have affected the selection of the BMP by the Janus(T) and Carmonette models. Nevertheless, each model's target selection algorithm does not necessarily guarantee selection of the same target. The selections of a BMP by Janus(T) and a ZSU by Janus(L) confirmed this assertion. The random draw determines which target is finally selected, and the weight factors only affect a target's probability of selection. The implementation of target priority values into the Janus(L) model's target selection process enables the user to choose which weapon will engage a selected target. Conversely, each possible target and weapon combination is randomly assigned a TR in the Janus(T) model.

The Carmonette and STAR models take a different approach to target selection. The range band is the driving force behind the target selection schemes utilized by these two models. However, there are some dissimilarities between the two models' methods of target selection. Particularly noteworthy are the models' different implementation techniques regarding range bands and priority lists to determine which target will be selected. In the Carmonette model, the user establishes target and weapon pairings which must satisfy slant range requirements in order for the target to be eligible for selection. This step is nonexistent in the STAR model since its target selection process enables the user to input or assign target and weapon pairings directly to range bands commensurate with the weapon's minimum and maximum effective range. In essence, the STAR model has taken the range band concept one step

further. Additionally, the Carmonette model employs three priority lists from which targets are selected, whereas the STAR model uses just one. Despite the above mentioned dissimilarities, it appears that under many conditions (e.g., all weapons having their basic load of ammunition) these two processes would result in the selection of the same targets.

The concept of ties and their resolution is another important aspect of a model's target selection process. An interesting phenomenon is that all four models use range in some capacity to resolve ties. The Janus(T) and Janus(L) models utilize the number of cycles generated and PK respectively which are both range dependent. The closer a firer is to a target, the higher the value assessed to the number of cycles generated and PK which results in the target associated with these values being selected. Simply stated, when ties occur, the target closest to the firer is selected. The Carmonette and STAR models take a more direct approach with regard to utilizing range as a discriminator. The decision logic applied to the target selection process of these two models resolves ties by simply selecting the target closest to the firer.

In summary, there are two basic target selection methodologies represented and implemented in the four high resolution combat models presented in this study. Although each model's target selection methodology possesses distinct characteristics, an overall assessment results in two separate groupings. The target selection methods of both Janus models utilize weighting factors and a random draw to select a target. Due to the randomization aspect of the Janus models' target selection processes, the only conclusions that can be drawn with regard to correlation between these two models are those mentioned in the preceding statement. On the other hand, Carmonette and STAR employ the range band concept which does not involve the use of randomization. These two processes appear to be highly correlated and would select the same target for engagement under most scenario conditions. The resolution of ties, an integral part of target selection, was consistent among the four models. Although some differences exist between the four target selection schemes, the models can still be categorized overall as adhering to one of two target selection methodologies: weighting factor (Janus models) or range band (Carmonette and STAR models).

## D. TVA AND TARGET PRIORITY

The TVA and target priority processes of each model significantly impact on their respective target selection functions. The matrices on pages 85 and 86 (Figures 4.7 and 4.8) emphasize the distinct characteristics of these processes.

TVA is important both prior to and during the simulated battle. In three out of the four models, the user establishes TVA during the initialization stage. The TVA process within each of these three models is supplemented by a mechanism peculiar to that model (see Figure 4.7). The Janus(T) model establishes its TVA by a random draw thus introducing randomization into the target selection function at the outset.

TVA during the battle is primarily accomplished by accessing PH/PK data coupled with features unique to each model (see Figure 4.7). It must also be noted that the Janus(T) model continues to use randomization in the TVA process during the battle as well.

The Alpha concept implemented by the STAR model takes a dynamic approach toward TVA. Target worth is a changing process based on previously incurred damage. Each succeeding iteration of TVA applies the results of previous efforts (by category) and is weighted (influenced) toward targets similar to those previous engagements which met with success. The other model's TVA during the conduct of the simulated battle depends on pre-game data inputs and is static throughout the game.

Target priority lists are the basis on which ultimate target selection is made. All four models require that a target be acquired before it is eligible for selection. The NVEOL detection model is the means by which targets are acquired in all four models. However, the Janus(L) model is also equipped with the ASARS detection model which provides it with an additional means for acquiring targets.

The use of the NVEOL model in both Janus models does not end with target acquisition (see Figure 4.8). The detection model is further utilized to establish potential target lists and maintain target prioritization during the conduct of the simulated battle. The user or commander has no way of influencing the potential target lists created within the Janus (T) model since the list's targets are determined by comparing a randomly assigned threshold ratio (TR) to a model generated cycle ratio (CR). Although the potential target list procedure is similar in the Janus(L) model, it does allow for user interaction in that the weapon selection is based on the commander's target priorities. Despite this apparent enhancement of Janus(L) over Janus(T), the resulting target selections would likely be the same. This declaration is predicated on the premise that the Janus(T) model builders solicited and incorporated the opinions of reputable sources into their hard wired weapon selection decision logic.

The Carmonette and STAR models do not utilize the potential target list approach. The priority lists of these two models are established by the user or commander. However, Carmonette is unique in that it is the only model to incorporate target class into its target priority process. Target prioritization during the battle is somewhat predetermined since there are three priority lists which are exhausted sequentially (see Figure 4.8). The STAR model's target prioritization is based on user preferences. The user redesignates input values to change range bands and targets of military interest during the simulated battle.

In review, each model requires that a target be acquired prior to being eligible for selection. The Janus models both use potential target lists while the Carmonette and STAR models rely on user inputs to develop target priority lists. These potential target lists or priority lists represent the foundation on which each model's target selection function is built.

| | Prior to Simulated Battle | During Course of Simulated Battle |
|---|---|---|
| Janus(T) | Initialization stage - each possible combination of observer unit (direct firer) with enemy target unit is assigned a "threshold cycle ratio" (TR) by a random drawing. | Direct Fire Module (DFM) - makes preliminary kill assessment once a target has been selected and initially engaged by comparing a "U(0.1) random draw" to the previously calculated SSKP If the U(0.1) random draw is less than or equal to SSKP, target is assessed as a valid kill at impact time. |
| Janus(L) | "PKEDIT Program" - which creates and examines the effectiveness (value) of each weapon type against each target type based on user input.<br>"PKEDIT Program" - consists of PH and PK curves which are used to resolve direct combat situations, based on the scenario.<br>PH/PK data is obtained from a Master Data Base (MDB) - contains all data available for each target/firer pairings. | Essentially the same as prior. MDB accounts for the four types of kills and defilade or exposure status of targets which are reflected in the PH/PK data.<br>Upon arrival of a round at a target, a stochastic (event by event) assessment is made based on the lethality of the weapon (PH and PK curves) which are dependent on the vulnerability status of the target (stationary, moving, or in a prepared position). |
| Carmonette | Unit Orders - to be executed during the simulation.<br>Each unit is given a complete set of orders which includes its tactics, movements, and firing doctrine.<br>Unit Orders are applied to user input target and weapon pairings. | PH and PK are determined by the firing weapon type, target's aspect angle, range, vulnerability class, and defilade status. PH and PK obtained from source data. |
| STAR | User inputs - attributes assigned to targets<br>User pairs targets and direct fire weapon systems, so that targets are engageable by weapons (i.e., within range constraints of weapon). | Concept of Alpha - percent of previously incurred damage. Alpha tables provide probabilities of (hit, no kill, and the four types of kills) as succeeding rounds are fired at targets. Changing probabilities or Alpha values reflects TVA during the simulated battle. |

Figure 4.7 TVA Prior to and During Simulated Battle.

| | Potential Target Lists | Priority Considerations | Prioritization During Battle |
|---|---|---|---|
| Janus(T) | Weapon/target pairings are computer generated during the initialization stage. Each possible weapon/target combination is assigned a TR by random draw.<br>NVEOL model used to establish potential target lists and determine whether or not the target is acquired.<br>*List consists of five potential targets.* | NVEOL:<br>1. Target in firer's search sector.<br>2. Firer's LOS to target.<br>3. CR greater than or equal to TR.<br>Ties - number of generated cycles (i.e., five targets with most cycles are put on the list) which equates to *range* (closest to firer). | Every 20 seconds of game time, a list of at most five potential targets is *formed*.<br>The five targets with the most cycles and satisfying the "requirements" implied by the conditions in column two comprise the potential target list after each time step. |
| Janus(L) | Weapon selection for each possible target is determined based on the commander's target priorities.<br>NVEOL (same as above) or ASARS models used to establish potential target lists.<br>ASARS model establishes potential target list by taking the five targets which have the smallest angular distance from the firer's primary direction of view. All targets on the list are eventually acquired unless LOS is lost. | NVEOL - same as above.<br>ASARS:<br>1. Target within firer's sector.<br>2. *Firer's LOS to target.*<br>3. Target within range of firer's weapon.<br>NVEOL Ties - (same as above)<br>ASARS Ties:<br>1. Prior to acquisition - range (closest to firer)<br>2. After acquisition - PK (highest value) which usually means range (closest to firer). | Using the NVEOL model, potential target lists are regenerated every 8 seconds.<br>The five targets with the smallest angular distance and satisfying the "requirements" implied by the conditions in column two comprise the potential target list after each time step.<br>Once a target is acquired, it becomes a possible target and will appear on the screen.<br>Acquired targets are "bumped" if LOS is lost during battle. |
| Carmonette | The commander or user establishes three priority lists based on his perception of what the target priority should be.<br>Targets are further ranked within each list based on target class.<br>Targets must be acquired using the NVEOL model before being eligible for selection from any of the lists. | 1. Range<br>2. Target Class<br>3. Ability of weapon system type to engage target.<br>Ties - select target *closest to firer.* | Priority one list must be exhausted before moving to list 2. Note: the same guidelines apply when moving from list 2 to list 3.<br>*If a priority one target is acquired* even after priority list 2 or 3 has been started on, it will be engaged immediately. |
| STAR | User selects ammunition type to be used against target.<br>User prioritizes targets by assigning highest priorities to both targets of and their respective range bands.<br>Targets must be acquired using the NVEOL model before being eligible for selection from the priority list. | 1. Target weapon system type.<br>2. Range to target (considered in several different range bands).<br>3. Ammunition type to be used against this target.<br>Ties - select target closest to firer. | The user prioritizes all potential targets during the pre-game phase of the simulation run. |

Figure 4.8 Target Priority Methods of Each Model.

## E. STRENGTHS AND WEAKNESSES OF MODELS

The assessment of the models' strengths and weaknesses is subjective and is addressed with regard to the question, " How accurately does the model depict target selection under actual combat conditions? ". In light of this fact, the models' strong and weak points (as viewed by the author) will be discussed in the same context when appropriate, thus facilitating the reader's ability to form his own opinion.

The resemblance of each model's target selection function to that dictated by "doctrine" is a tribute to the combat model builders' ability to depict target selection. It appears that the right issues are being addressed and effectively incorporated into the models' target selection algorithms. Although these algorithms appear to be in sync with "doctrine", incorporating the uncertainties of human behavior is extremely difficult.

The Janus models utilize randomization in their target selection processes to account for the unpredictability of human behavior in actual combat. Introducing randomization into the target selection process can compensate, somewhat, for human behavior; however, it can also result in the neglect of a prioritized target. Randomization in the target selection process can be used to represent firers in various combat situations. For example, a firer in combat might select targets based on his own intuition which may not be in accordance with doctrine, or choose not to fire at all. Randomization can also result in a prioritized target failing to be selected. In the Janus models, there are two ways this can occur. First, the random process by which the potential target lists are established hinders a target's chances of even being considered for selection. Secondly, targets eligible for selection are assigned a weighting factor and must overcome yet another stochastic draw to be selected for engagement. Though the potential target list procedure is governed by randomization, it does provide frequently regenerated target lists (i.e., every 6 to 20 seconds) during the course of the simulated battle, thus depicting the tactics of opposing forces in actual combat and changing a target's probability of being selected.

The Carmonette and STAR models both adhere to the user or commander established priority lists. This concept ensures that all prioritized targets are eventually considered for selection. The user is afforded the opportunity to take advantage of the model as a training mechanism since the selected targets are a direct result of his inputs and can be analyzed as such. The drawback to this approach is the absence of spontaneity during the conduct of the simulated battle. This is exemplified in the

Carmonette model. After the priority lists for a specified FOV have been established, they cannot be altered for a user designated period of time. No new targets, regardless of priority, can be selected within this FOV until the designated time has elapsed. This facet tends to detract from the model builders' inherent goal of depicting target selection under actual combat conditions.

The target selection methodologies employed by the four models in this study only take first order effects into account. The modeling approach that implements the interaction of several state variables could provide additional information, thereby increasing the model's accuracy in depicting target selection under actual combat conditions. Additionally, in actual combat, the tactical situation is constantly changing thus requiring the commander to be very flexible in his decision making process. The four methodologies do not provide the user with a means of altering pre-game input data after the simulated battle has begun. Therefore, initial input data cannot be changed regardless of developments during the course of the simulation.

Regardless of the techniques or approaches implemented by the model builders, intangibles (morale, leadership, and training) cannot be quantified and accurately depicted by a target selection function for friendly or opposing forces. The lack of empirical data and doctrinal knowledge with regard to the opposing forces inhibits the model builders. Further, the output generated by the models' target selection processes is only as reliable and credible as the user who controls the input data. The level of expertise or knowledge coupled with the judgmental views of the user significantly impact on the generated output of the target selection processes.

The Janus(L) and STAR models exhibited an added feature over the other models. The target priority value concept of Janus(L) enhances its ability to depict target selection under combat conditions. The commander determines which weapons should engage various targets in combat, and this feature of the Janus(L) model allows the user to exercise his skills in this area. The STAR model also places the user in a situation similar to one that could be encountered in combat. The assignment of weapons to targets commensurate with the minimum and maximum range of that weapon is something at which combat leaders should be proficient. All of the models' target selection algorithms provide a tool for the analysis of doctrine and tactics. Further, the models provide commanders with an opportunity to train and exercise their subjective interpretation of target selection just as they would have to do in actual combat.

# V. CONCLUSIONS AND RECOMMENDATIONS

## A. CONCLUSIONS

Investigating the target selection methodologies of four high resolution combat models provided detailed information about the algorithmic procedures employed by model builders to depict a direct firer's target selection under actual combat conditions. Each of the four models possesses idiosyncrasies peculiar to its target selection function; however, two basic methodologies evolved from this study. The weighting factor approach is employed by the Janus models while Carmonette and STAR utilize the range band concept.

Subjective evaluation of all the algorithms' depiction of a direct firer's target selection under actual combat conditions showed parallelism between the model builders' decision logic and "doctrinal rules" when the models were analyzed under the assumption or existence of ideal conditions. The notion of ideal conditions implies that the impact of those factors (intangible variables) over which the model builder has no control are negligible. Nevertheless, these factors represent a truism which cannot be ignored. As would logically be expected, accurate algorithmic depiction of the intangible variables impacting on a direct firer's target selection proved to be quite a problem for the model builders. The algorithms of the four models in this study depicted, with a high degree of fidelity and consistency, those aspects of target selection dictated by doctrine that the model builder could easily substantiate and transform into decision logic. The consistency among the target selection schemes was very encouraging from the standpoint that it appears model builders generally agree about target selection doctrine and its depiction. Hopefully, the agreement exhibited by these four models with respect to their target selection schemes is indicative of combat modeling approaches Army-wide.

The benefits derived from using target selection algorithms appear to far outweigh the ever-present inability of model builders to accurately depict the intangibles of actual combat. The user or gamer inputs target selection data prior to the battle simulation runs, thus enabling leaders to sharpen their tactical skills and analyze the results of their decisions in a noncombat environment. As model builders continue to improve target selection schemes, leaders are continuing to use them as

training mechanisms. One day, there may even be a place in actual combat for target selection algorithms to assist the Army's leaders and combatants in their decision making process. In this role, target selection algorithms would be an aid in optimizing target selection.

## B. RECOMMENDATIONS

The following recommendations are made for further investigation and study:

1. An extension of the regression equation, which was derived in the Broussard thesis (discussed in Chapter II), to other possible firer and target types could result in a viable target selection methodology [Ref. 5].
2. Modifications have been made to the direct fire target selection algorithms of the Janus(L) model, and the documentation is currently under review. Investigating these revised algorithms may provide new insight and useful information with regard to target selection.
3. Inferences were made in this study concerning the lack of established target selection doctrine. A survey, involving the prioritization of steps to select single and multiple targets, given to combat veterans, could be used to formulate a base case with which the target selection methodologies of combat models could be compared.
4. Analysis of field test data could offer an operational view of target selection.
5. A mathematical modeling approach to optimize target selection with respect to appropriate combat effects measures should be developed.
6. Modified or simplified simulation programs, based on each model's algorithmic target selection methodology, could be developed. These programs might provide a means of analyzing the effects of varying input parameters and generate further information on the target selection algorithms.
7. The robustness of selected models' outputs under variations in the target selection algorithms should be examined.

## APPENDIX
## ACRONYMS USED IN THIS STUDY

The following acronyms are used in the text of this study.

| | |
|---|---|
| ASPS | All Source Production Section |
| APC | Armored Personnel Carrier |
| CSC | Conflict Simulation Center |
| CSDATA | The Combat Systems Data Editor |
| CR | Cycle Ratio |
| DCD | Directorate of Combat Development |
| DEC | Digital Equipment Corporation |
| DFM | Direct Fire Module |
| ETQ | Engageable Target Queue |
| FOV | Field of View |
| FSE | Fire Support Elements |
| G2 | Division Level Intelligence Section |
| HVT | High Value Target |
| IPB | Intelligence Preparation of the Battlefield |
| LOS | Line of Sight |
| MDB | Master Data Base |
| MLD | Minimum Level of Discriminate |
| NVEOL | Night Vision - Electro-Optical Laboratories |
| NPS | Naval Postgraduate School |
| PD | Probability of detection |
| PH | Probability of Hit |
| PK | Probability of Kill |
| PL | Priority List |
| RN | Random Number |
| SCENEDIT | Scenario Editor |
| SS | Search Sector |
| SSKP | Single Shot Kill Probability |
| Sys | System |
| Tgt | Target |

| | |
|---|---|
| TPV | Target Priority Values |
| TR | Threshold Ratio |
| TRASANA | TRADOC Systems Analysis Activity |
| TVA | Target Value Assessment |
| WF | Weight Factor |
| Wpn | Weapon |

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